THIRTEENTH REPORT

OF

THE MICHIGAN ACADEMY OF SCIENCE

CONTAINING AN ACCOUNT OF THE ANNUAL MEETING

HELD AT

ANN ARBOR, MARCH 29, 30, 31 AND APRIL 1, 1911.

PREPARED UNDER THE DIRECTION OF THE COUNCIL

BY

GEO. D. SHAFER
SECRETARY

BY AUTHORITY

LANSING, MICHIGAN.
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1911

LETTER OF TRANSMITTAL.

To Hon. Chase S. Osborn, *Governor of the State of Michigan:*

Sir—I have the honor to submit herewith the Twelfth Annual Report of the Michigan Academy of Science for publication, in accordance with Section 14 of Act No. 44 of the Public Acts of the Legislature of 1899.

Respectfully,

GEO. D. SHAFER,

Secretary of the Michigan Academy of Science.

E. Lansing, Mich., May, 1911.

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(Charter members are marked with an asterick.)

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REPORT OF THE TREASURER.

April 1, 1910—March 31, 1911.

Receipts:

Balance on hand	$43 31	
All other receipts	198 00	
Total	$241 31	

Expenses:

For reprints		$100 25
Postage and envelopes		9 18
Programs, announcements and letter heads		45 24
Express and dray		80
Stenographer		4 45
C. H. Kauffman		73
Geo. P. Burns		7 36
A. G. Ruthven		8 75
Janitor		2 00
Total		$178 76
Balance on hand March 31, 1911		62 55

Report of the Auditing Committee, March 31, 1911.

The accounts of the Treasurer were audited and found correct.

FRANK LEVERETT,
C. H. KAUFFMAN,
Auditing Committee.

COMPLETE LIST OF PAPERS AND ADDRESSES PRESENTED AT THE SEVENTEENTH ANNUAL MEETING OF THE MICHIGAN ACADEMY OF SCIENCE.

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2. Progress of the Geological and Biological Survey of Michigan:
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   Biology, A. G. Ruthven.

3. Conchological Survey of Michigan, Bryant Walker.

4. Map of Northern Peninsula of Michigan, Frank Leverett.

5. Distribution of Industries of Michigan, L. H. Wood.

6. Salt Districts of Michigan, C. W. Cook.

7. Earthquakes in Michigan, W. H. Hobbs.

8. Soil and Soil Problems from Standpoint of Physicist, J. A. Jeffery.

9. Soil and Soil Problems from Standpoint of Chemist, A. J. Patten.

10. Soil and Soil Problems from Standpoint of Microbiologist, Otto Rahn.

11. Soil and Soil Problems from Standpoint of Botanist, W. H. Brown.

12. The Theory and Practice of Soil Management, F. K. Cameron.

13. The Cold-air Engines Developed Above the Continental Ice-masses of the Polar Regions, W. H. Hobbs.

14. Railroad Distribution in Michigan, A. E. Parkins.

15. An Improved Jolly-balance for the Determination of the Specific Gravity of Minerals, E. H. Kraus.

16. Variations in *Camarotoechia* (*Rhynchonella*) *Huronensis*, R. A. Smith.

17. The Extent of the Anderdon Beds and Their Place in the Geological Column, Rev. Thomas Nattress.

18. Forest Fires of the West, Amos Maggy.

19. A Preliminary Report Upon the Salt Industry of Michigan, Charles W. Cook.

20. The Terrestrial Phase of the Permian in North America, E. C. Case.

21. The Process of Solifluction from Observations in Swedish Lapland and Southern Norway, W. H. Hobbs.

22. The Junction Angle of Streams, I. D. Scott.

23. Relation of the Ice-lobes in Minnesota, Frank Leverett.

24. A study of Ice-sheet Erosion and Deposition in the region of the Great Lakes. Frank B. Taylor.

25. The Culture of Nations. Mark Jefferson.

26. The Origin of Continental Forms, Howard B. Baker.

27. Introduction of Mineral Conservation in Michigan, R. C. Allen.

28. The Meaning of Soil Conservation, Joseph A. Jeffery.

29. Conservation of Michigan Forests, Filibert Roth.

30. The Future of Michigan Water Power, Lyman E. Cooley.

31. Conservation Work of the Public Domain Commission, Junius E. Beal.

32. Relation between Good Roads and the Conservation Movement, Frank Rogers.
33. Orthoptera Collected at Douglas Lake, Michigan, in 1910, Avalyn E. Woodward.
34. Observations on the Mammals of the Douglas Lake Region, Orrin T. Wenzel.
35. Odonata Collected at Douglas Lake in the Summer of 1910, Abagail O'Brien.
36. Results of the Mershon Expedition to the Charity Islands, Lake Huron: Mammals, N. A. Wood.
37. Ants, F. M. Gaige.
38. Beetles, A. W. Andrews.
39. Notes on Limnaea, H. Burrington Baker.
40. A Catalogue of the Mollusca of Michigan, Bryant Walker.
41. Notes on Michigan Reptiles and Amphibians, III, Alexander G. Ruthven.
42. Notes on the Amphibians and Reptiles of Cass County, Michigan, Crystal Thompson.
43. A Catalogue of the More Recently Described Species of Fresh-water Mullusca of North America, Bryant Walker.
44. Experiments with Chrysomelid Beetles, R. W. Hegner.
45. The Southwestern Center of Dispersal of the Unionidae, Bryant Walker.
46. Abnormalities in the Frog's Vertebral Column, H. Mac Curdy.
47. The Occurrence of a Cremaster Muscle in a Woman, G. M. Curtis.
48. The Spermatogenesis of an Orthopteran, *Ceuthophilus latebricolo.* Scudder, with Special Reference to the Accessory Chromosome, Crystal Thompson.
49. The Physiological Unity of the Neurone, H. MacCurdy.
50. Report on the Crustacea Collected by the University of Michigan, Walker Expedition to Southern Vera Cruz, Mexico, A. S. Pearse.
51. Notes on Michigan Crustacea, I., A. S. Pearse.
52. Notes on a Palaemon from Kamerun, A. S. Pearse.
53. The Mershon Expedition to the Charity Islands, Lake Huron: Plants, C. K. Dodge.
54. *Hepatica multiloba,* Apparently a New Species, S. Alexander.
55. *Quercus auriculata*, a Species of Oak New to Science, S. Alexander.
56. Plant Societies of the Costal Region near South Haven, Charles D. Nelson.
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64. Unreported Michigan Fungi for 1910, C. H. Kauffman.

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RECENT ACHIEVEMENTS IN PARASITOLOGY

FREDERICK G. NOVY.

It is well known that science in its varied branches has made wonderful strides during the past few decades. New modes of thought or points of view as well as new methods of attack have had much to do with the success achieved. Departments of science undreamed of before have thus come into existence and have attained rapid growth. As in the case of a new and fertile country where the pioneers' path is soon traversed by many settlers, so in this or that new science we find that its few explorers before long have many followers who devote themselves industriously to developmental work. At no time in the past has there been such a large number of workers engaged in science as at the present day, and it is because of this large number of devotees that so much, quantitatively at least, is accomplished. Rapid exploitation of a promising field is a rule in the crowded business life and is none the less observed in science. It is the inevitable result of the conditions which obtain today, namely an ever-increasing number of trained men, rapid means of communication, and an abundant opportunity for publication. The path of progress, however, need not be and indeed is not always straight for the reason that problem, method and observer are subject each to its peculiar variation or inaccuracy. Yet after all, errors such as they are soon become corrected and some real advance is made.

The achievements for the decade just closed make a most interesting chapter in the history of science and augur well for the new century. To attempt a general survey of a decade's scientific work would be to say the least inadvisable and it is not my intention to undertake such a task. I have thought, however, that it would not be out of place to present a brief account of some of the more notable results in fields of work with which I have some acquaintance.

The control and eradication of disease has been a fruitful topic for research ever since Pasteur paved the way, first by his remarkable studies on the silkworm disease, then by his classical studies on attenuation, especially that of the virus of anthrax and rabies. In the case of the silk-worm disease which threatened to impoverish France, Pasteur practically put an end to the malady by developing means for its detection and prevention. The corpuscles of Cornalia which we today recognize as the spores of a protozoon (*Nosema bombycis*) were not considered by him as the cause but rather as reaction products comparable to tubercles and cancer cells. Nevertheless he realized their diagnostic importance and by finding these bodies in the dust and sweepings of rooms where the worms were raised he was led to believe that the worms became infected by feeding upon the leaves laden with the infected dust. A series of tests confirmed the belief and gave, what we realize today, the first experimental transmission of a protozoal

disease. In this the genius of Pasteur was far ahead of his day, for fully a quarter of a century passed before the transmission of a second protozoal disease, namely Texas fever was revealed. Furthermore, the recognition of the mode of spread of the disease together with other facts acquired enabled Pasteur to put a permanent check upon the progress of the disease.

The suppression, if not extinction, of disease of parasitic origin, is obviously the chief motive which underlies all investigation of pathogenic organisms. The investigator himself may not realize the fact, and indeed be quite unwilling to accept such an interpretation, but nevertheless in his innermost self he hopes that his work may lead to some practical result in alleviating suffering; directly, if it concerns disease of man or beast; or, indirectly, in improving human conditions where the studies deal with problems of husbandry. The border-line between pure and applied science becomes, as a rule less definite the more closely a science touches the every day affairs of mankind. Thus, it is, that the work of Pasteur, a follower of pure science, opened up an era of human progress which in a large measure has already given mankind mastery over the living causes of disease.

MALTA FEVER.

The practical extinction of Mediterranean or Malta Fever affords an example of more than ordinary interest. The organism responsible for this disease, (*Micrococcus melitensis*) was discovered as early as 1887, but the mode of transmission was not cleared up until about five years ago. At first, supposed to be restricted to the harbor of Valetta, the disease has since been recognized in nearly all Mediterranean ports, and, indeed, in many parts of the world. The fact that its army and navy paid a constant and heavy toll to this disease eventually caused the British Government to send a special commission to investigate the disease. In 1907 after three years of study the Commission successfully concluded its work. How well they succeeded will be realized when it is said that while formerly more than 600 soldiers and sailors in Malta were sent annually to the hospital, to remain there for an average period of four months each, the very first year in which protective measures were enforced (1907) the number of cases fell to seven all told.

How was this remarkable result brought about? The specific organism was known to be present in the blood of the patients, but that itself was not enough. It was necessary to find out whence it came, how it got into the body and how it left the body. It was easy enough to demonstrate that the organisms left the body principally through the kidneys. It might also leave the body by means of blood sucking insects but the supposition that the disease could be spread in this manner (as in the case of malaria, yellow fever, etc.) could not be verified by experiment. Mere contact with the sick, or the inhalation of the dust of infected quarters did not cause the disease. On the other hand it was soon learned that the disease could be given to monkeys by injection, or, what was vastly more important by feeding even a small number of the germs. The indications therefore pointed strongly to the food as the vehicle and to the alimentary canal as the avenue of in-

fection. Then came the wholly unexpected observation that the blood of several goats agglutinated or clumped the micrococcus, thus indicating that the goats had in all probability the same disease. The Commission then examined thousands of the goats on the Island of Malta and found that fully 50 per cent gave the agglutination test while 10 per cent were actually secreting the micrococcus in the milk.

The surprising fact was thus established that the disease was really a milk infection and that the disease was primarily one of the goat. Equally astounding was the demonstration that the seemingly healthy goats continue to eliminate the specific germ in their milk for many months after the disease had passed away. The recognition that Malta fever was a milk borne disease and that the goat was probably the only carrier enabled the institution of the simplest measures for its suppression.

CARRIERS.

This brief statement covering the main facts in regard to Malta fever, serve to bring forward an exceedingly important factor in the transmission of communicable diseases, namely the existence of so-called "*carriers*." This term is applied to animals or persons who, though apparently in perfect health, harbor and eliminate a given disease germ. Usually, though not necessarily, the carrier has recovered from an attack of the disease and therefore enjoys immunity. This immunity while affording perfect protection against the injurious organisms is not always able to bring about the destruction of the latter which accordingly persists in the body for a variable length of time.

The existence of carriers is not altogether a matter of recent discovery, but rather a fact which has received wide confirmation and consequently has led to the recognition of its full importance. That apparently healthy persons could harbor in their mouths the germ of pneumonia, or of diphtheria became known in the early eighties about the time that these organisms were discovered. Later, it was shown that after recovery from diphtheria, the specific bacillus could persist in the throat in a small percentage of the cases for several weeks, and even months, and at the same time maintain its virulence. It was seen that such a carrier could spread the disease just as readily as the sick person and hence sanitarians very properly demanded that the isolation of the individual be continued after recovery and until the disappearance of the disease germ itself.

It is only within the past few years that the role of carriers in typhoid fever has come to be fully realized. The majority of typhoid patients, after about the 12th day, eliminate the typhoid bacillus in the urine, at times in enormous numbers, and such elimination may continue for several weeks after complete recovery has taken place. Exceptionally the typhoid bacilli may persist in the urine or in the discharges for years, if not through the remainder of life. Hence efforts at the control of typhoid fever outbreaks must be directed quite as much against the possible carriers as against the actually sick.

The studies on Malta fever, as pointed out, have shown that the goat is the natural carrier, the germ localizing in the mammary gland and hence appearing in the milk. In man this disease presents a condition analogous to that recognized in typhoid fever, that is to say, the germ

is eliminated from the kidneys for weeks, and even months after recovery and hence man as well as the goat becomes a carrier. In cholera, dysentery and other bacterial diseases this same problem of carriers is one that claims attention but it is not my purpose to do more than point out this fact.

But carriers are not restricted to the bacterial diseases which have been mentioned. They play an even more important part in the propagation of certain protozoal infections. They constitute the natural reservoirs of virus and, as such are chiefly responsible for the continued existence of such diseases. Thus, cattle which have recovered from Texas fever do not show on microscopical examination of their blood any evidence of the presence of the parasite, and yet such blood when injected into a healthy animal gives rise to the typical disease. The parasite is present in an unrecognizable form in the immune animal; a fact which implies that a reciprocal immunity has been established, an armed truce, so to speak, between the host and the invader.

In spirochete and trypanosomal diseases carriers are again in evidence. Here also the organisms, though present in the blood are unrecognizable by means other than inoculation of animals and exceptionally by artificial cultivation. It would be interesting to know just what form is assumed by these parasites which enables them to escape direct detection. Some indication of this transformation is already at hand and will be referred to presently.

The disease caused by sub-microscopic or invisible organisms may show this same persistence of the infective agent long after recovery has taken place. A striking example of this fact has but recently been determined in connection with infantile paralysis. It has been found that the virus persists in the naso-pharynx for many months. Under such circumstances it is not surprising to learn of sudden outbreaks of this dangerous disease in a locality where no previous case was known to exist.

INSECT CARRIERS.

There remains another type of carrier, other than man or the ordinary animal, namely the insect or arthropod or other sanguivorous host. It may be said at once, and without any fear of contradiction, that the greatest achievements, the most valuable results which have been obtained during the past 10 or 12 years have come from the recognition of the important part played by these carriers in the transmission of disease. There were, indeed, years ago, prophets who pointed out the probability that malaria and yellow fever, were mosquito borne diseases but the experimental proof was not furnished until quite recently. The early bacteriologist could see only three ways for the transmission of disease, namely inoculation through wounds, inhalation of dust particles, and infection of food and water. That seemingly insignificant bites of insects could result in the production of serious disease did not appear reasonable and for that reason when the American workers in 1891 pointed out that Texas fever was caused by the bite of a tick, and further, that the tick in question had never been in contact with a diseased animal, but had developed from eggs laid by its blood-sucking parent, it was not surprising that open scepticism if not actual ridicule was bestowed upon the work.

It was not until 1898 that the far-reaching discovery was made that a human disease, namely malaria, was transmitted by the bite of a certain kind of mosquito. It was indeed a revolutionary discovery which relegated the time-honored causes, such as effluvia, miasms, and bad odors to the junk-pile of exploded theories and substituted for these demonstrable biological facts. The unveiling of the mystery surrounding malaria resulted in a new and clearer conception as to the transmission of certain diseases, particularly those in which the germ is present in the blood of the diseased animal. The fact is now fully appreciated that insects and the like which feed upon the blood of such diseased animals may become infected; in other words, they furnish suitable soil for the growth of the germ. It must not be inferred, however, that every kind of blood-sucking organism which feeds upon a given animal will constitute a host for the parasite. There are just as great differences in susceptibility among the insects and arthropods as there are among the higher animals. The fact that man may contract a disease or become poisoned by eating certain kind of food does not mean that the lower animals will respond in a like manner. Nor does it follow that a disease of the horse or cow is transmissible to amphibians or birds. The common mosquito (*Culex*) for example does not transmit malaria for the reason that the organism of this disease cannot pass through the necessary development and multiplication in this insect. A special mosquito of another genus (*Anopheles*) does afford suitable conditions for the growth of the germ and hence becomes the carrier. A further illustration is afforded by yellow fever which is not transmitted by either one of the two mosquitoes just mentioned but has its own special host (*Stegomyia calopus*).

PASSIVE AND ACTIVE CARRIERS.

It has been customary for some years to speak of insects as passive and as active carriers, and these terms usually convey with them certain well-defined conceptions. The passive carrier may be looked upon as an accidental conveyer rather than as a living host for the organism. A fly feeding upon typhoid excreta may soil its feet or proboscis and on alighting elsewhere may deposit such mechanically adhering particles. The part played by the passive carrier is merely one of bringing about indirect contamination. This transference of disease organisms to various articles of food or even into wounds, by flying insects may lead to infection and it is generally recognized that certain bacterial and even protozoal diseases may thus be spread. Reference need only be made to cholera, dysentery, tuberculosis, and typhoid fever.

The passive carrier is by no means as important a factor in the spread of disease as is the active carrier. Indeed, it cannot be compared with the latter for the reason that the active carrier usually represents the only natural way by which certain diseases are transmitted. The innumerable researches of the past few years all go to demonstrate the preponderating role played by the active carrier. Every day, so to speak, brings new and positive evidence regarding the transmission of this or that disease by active hosts, and for that reason this factor is deserving of special attention.

An active carrier is essentially a diseased individual. The insect,

tick, leech and the like which feed upon the infected animal may become a suitable soil for the disease organism in which case it multiplies directly, or else it passes through a developmental cycle. It has been supposed by some that active carriers can harbor only animal parasites such as the pathogenic protozoa and certain worms (filoria) an assumption which is certainly erroneous. It is undoubtedly true that in the majority of known active carriers the organism which is transmitted is of an animal nature but that fact is not sufficient to exclude the bacteria, nor does it justify the assumption that an unseen and unrecognizable germ which is transmitted by an active carrier is *ipso facto* a protozoon.

Too much stress can hardly be placed upon the fact that the ordinary bubonic plague, the cause of which is a typical bacillus, is spread almost wholly by the bites of fleas which come from diseased rats, ground squirrels and other rodents. The isolation of the diseased patient is not enough to prevent new cases from developing. The protective measures must include the utmost eradication of rodents and their ectoparasites.

The splendid studies of Rickett's have shown that the so-called "Rocky Mountain Fever" or Spotted Fever is in all probability due to a bacillus, and furthermore that it is invariably transmitted by the bite of a tick or of its offspring.

Other examples of active carriers of bacterial organisms are met with in connection with certain spirochete infections, of birds, mammals and man. The best example of the latter type of infection is the African Tick Fever. The active carrier in this case is a tick (*Ornithodorus moubata*) and the disease is transmitted not only by the tick but also by its offspring. In other words, we have here, as in the case of Texas fever, and Spotted Fever, a hereditary transmission of the parasite from the parent through the egg to the young tick. Instances of such hereditary transmission are common enough in the case of the Tick family but are rather exceptional with the mosquito and other insects.

Our knowledge regarding the changes which the spirochete undergoes in the tick and in the egg is by no means fully established. While some worker, such as Koch, have described the presence of the spiral organism in the internal organs and in the eggs, other observers have failed to demonstrate their presence. The recent observations of Leishman are pregnant with future possibilities and for that reason call for a brief mention. Leishman in his work was unable to detect recognizable spirochetes in ticks, later than the 10th day after ingestion. Instead he observed clumps of chromation granules which were also invariably present in the eggs, larvæ and nymphs derived from infected ticks. Whether these granules are of spirochete origin is uncertain, for Leishman himself found similar granules in nymphs derived from ticks fed on normal blood. Inoculation of suspensions of such granules, which apparently contained no spirochetes, gave the typical infection in mice. Future work must determine the real significance of the Leishman granules. If it should be proven that the granules represent a developmental phase of the spirochete it would in some measure uphold the view of Much, Fontes and others that the tubercle bacillus is capable of existing in a similar form.

It has been heretofore quite generally accepted that the transmission

of a disease by a biting insect implies the injection of the virus into the wound. While this is certainly the case in malaria, it is not so in plague. There the infection is contaminative; in other words the excreta and not the saliva of the flea contains the plague bacillus. Leishman has brought forward evidence which indicates that an exactly similar condition exists in the case of the tick which transmits the African relapsing fever. And, it may be added further, that a like view for the transmission of the *Trypanosoma lewisi* by the rat flea has been suggested by Minchin and Thomson. Future studies will be needed to decide just how frequent is this contaminative infection.

In each of these three examples just referred to, the infective organisms develop particularly in the alimentary canal. In other words a veritable tube culture may result irrespective as whether the organism belongs to the bacteria or protozoa. A certain interval is needed to secure such multiplication before infection can be possible. As in the case of man and higher animals, the organisms which are introduced into the intestine may in time leave the alimentary canal and pass into the circulation, eventually reaching distant organs, such as the salivary glands.

The typical active carrier is where the parasite passes through a complex cycle of development in the insect, eventually appearing in the salivary gland in a new and minute form. This sporozoite stage is then injected into the wound and thus gains direct entrance into the blood. The classical example of this cyclical infection is afforded by malaria.

SPIROCHETES.

The studies of Schaudinn (1904) on the blood parasites of the little owl (*Athene noctua*) may be considered as epoch-making even though the conclusions which he reached have not been substantiated by other workers. These studies concerned two very common intra-cellular parasites of hawks and owls. One of these, the halteridium, if found within the red blood cells, and Schaudinn believed that this parasite, after fertilization, developed in the gut of the common mosquito (*Culex pipiens*) into innumerable minute trypanosomes, which, by the bite of the insect, were subsequently introduced into the circulation of clean owls and became transformed into the original intracellular parasite.

It is beyond the scope of this address to go into a detailed consideration of the many researches made since that time to confirm or disprove Schaudinn's view that the intracellular halteridium is but a resting stage of a flagellate or trypanosome. In collaboration with Dr. MacNeal we showed that the morphologic methods employed were insufficient and uncertain and hence quite naturally led to wholly erroneous conclusions. The method of cultivation of trypanosomes as devised by us offered the only means of a crucial experimental test of his conclusions. If the halteridium developed into flagellates, these should be cultivable *in vitro* and with such pure cultures the questions raised should be readily answered. By this means it was possible to demonstrate that cultures could be obtained from the blood of birds even though no intracellular parasites were present. Moreover, the blood of birds having halteridia, frequently failed to develop such cultural flagellates. In other words, it was shown that there was no relation between the intracellular parasite and the flagellate or trypanosome and that the latter,

therefore, are entirely independent parasites. The fact that no trypanosome may be found in the blood of an animal by direct observation, even after the most careful search, is no proof of the absence of flagellates. A positive culture under such conditions is conclusive evidence as to their presence. Notwithstanding this fact, recent workers such as Rosenbusch and Mayer, by isolating cultures of flagellates from the blood of owls, and from the gut of mosquitoes which have fed upon such owls, believe that they have confirmed Schaudinn's conclusions.

Of considerably more importance was the work of Schaudinn with the second blood parasite of the owl, known as *Leucocytozoon Ziemanni*. This parasite he believed to be the resting stage of a very large trypanosome, and that, on fertilization, it developed in the gut of the mosquito into innumerable slender flagellates or spirochetes. These spirochetes were believed by him, at the time, to have the structure of trypanosomes from which they differed, however, in the mode of agglutination. Our investigations have shown that these views, like those regarding the halteridium, are untenable.

The most important result of these studies on the parasites of the owl was, without doubt, the special training which Schaudinn thus acquired. The skill and technique developed in the study of these organisms which seemingly possess but a purely scientific interest was utilized, a few months later, in the enduring research which resulted in the discovery of the cause of syphilis (1905). This was the crowning achievement of his life and it is truly regrettable that this indefatigable worked did not live to witness the practical results which followed so closely upon his discovery.

The *Spirochaeta pallida*, the cause of syphilis, is a delicate spiral, motile organism which is placed by some among the protozoa, by others among the bacteria. The question of its systematic position is of relatively little importance at present. It is, however, reasonably certain that the spirochetes do not possess, as has been claimed, the structure of trypanosomes.

The discovery of the germ of syphilis developed an intense interest in other spirillar diseases of man and the lower animals. It is not surprising, therefore, that our meagre knowledge regarding the spirochete infections was rapidly widened. While it has not been possible as yet to cultivate these organisms there can be no doubt but that this will be accomplished in the near future. At the present time, the organisms can be maintained in the laboratory only by continuous passage through susceptible animals. This is especially true of the various strains of spirochetes which cause relapsing fever in man and somewhat similar diseases in chickens and geese.

TRYPANOSOMES.

Among the protozoa there is no more interesting group of parasites than that of the flagellates or trypanosomes. Their extremely common occurrence, the ease with which many of the pathogenic forms can be maintained in laboratory animals, and the fact that many of these organisms can be cultivated in the test-tube render them objects of special interest. This is all the more evident when it is borne in mind that in the tropics many diseases of animals, and even of man, are due to organisms of this group.

Briefly stated, the trypanosomes are free-swimming parasites found in the blood plasma of vertebrates. They possess a nucleus, micro-nucleus, undulating membrane and a free flagellum. It is by aid of the undulating membrane and the whip that the parasites are able to move about quite freely in the blood of the host.

Up to ten or twelve years ago the number of known trypanosomes was rather small and about the only available representative was that found in the common wild rat. The *Trypanosoma lewisi* of the wild rat was therefore selected for experiments having for their object the development of a method of cultivation. With the aid of Dr. MacNeal this was accomplished, in 1903, and since then the blood agar method of cultivating flagellates has been widely and most successfully employed. This method has been found especially applicable in the study of the trypanosomes which are not markedly pathogenic, such as those found in birds, fish, amphibians, insects and some mammals. Of the pathogenic forms *Tr. brucei*, the cause of nagana or the tsetse-fly disease of South Africa, is the only one which has been carried through a series of artificial cultures. Much effort has been expended to bring under cultivation the parasites causing the diseases known as Surra, Dourine, Caderas, Human Sleeping Sickness, etc., but without satisfactory result. It is reasonably certain, however, that before long the difficulties will be overcome and that all of these parasites will be known in their cultural forms.

The importance of the cultural method in the study of trypanosomes is no less than in that of bacteria, moulds, yeasts, etc. In the first place, it enables the worker to detect the presence of a flagellate, even when it is present in such small numbers as to escape observation by the microscope. We have shown this to be true for the blood of birds and rats. During the past year a number of observations in different parts of the world have been made demonstrating the presence of trypanosomes in the blood of cattle, though none could be detected by other means.

Another advantage of the cultural method is that it affords additional means for the differentiation of species. The cultural characterists may vary considerably, as in the case, of bacteria, and hence this feature is one which may assist in the identification of the blood forms. The trypanosomes as found in the blood of different animals often present only slight differences in form or size, and specific names are only too often given because of the mere fact that the hosts are unlike species. In the case of birds, we have shown that the same cultural trypanosome may be found in very different species and what is more important that a given bird may be infected with two, culturally very different kinds of trypanosomes. The failure to recognize these important facts have led observers such as Rosenbusch and Mayer to erroneous conclusions regarding the parasites cultivated from owls. The flagellates which are present in the gut of insects, growing as they do upon dead material, must be regarded as cultural forms. This view is supported by the fact that when such organisms, for example those found in the mosquito, are cultivated in the test-tube they present essentially the same characteristics.

A further application of the cultural method is evident in connection with problems of immunity. It was because of the availability of pure bacterial cultures that so much has been done in recent years in experimental immunization to disease, and it is reasonable to believe that

similar results may be obtained with pure cultures of trypanosomes. This expectation has already been fully confirmed as regards one of these organisms, namely, *Tr. lewisi*, the parasite of the common rat. Several years ago it was shown that dialyzed, dead cultures of this organism when injected into the rat, protected this against the living virulent organisms. The production of an attenuated living strain which could be utilized as a vaccine was not realized until recently. With the help of Mr. W. A. Perkins we have shown that *Tr. lewisi* after passing through about 200 generations or transplants, in the culture tube, becomes attenuated so that it is no longer capable of infecting a clean healthy rat. Moreover, rats which have had such inoculations are perfectly protected or vaccinated against infection with the virulent organisms. This, it may be said in passing, is the first example of successful immunization of a susceptible animal by means of living protozoal cultures. The success obtained in this instance warrants the belief that similar results may be secured with the other, the more strictly pathogenic trypanosomes.

SLEEPING SICKNESS.

The interest in trypanosomes because of their causal relation to such animal diseases as surra, nagana, dourine, and caderas was more than doubled by the discovery that a similar parasite was responsible for the fatal human disease known as Sleeping Sickness. Though known for a long time on the west coast of Africa, this disease attracted but little attention prior to the close of the last century. The commercial development of equatorial Africa undoubtedly led to its wide dissemination. The apparently sudden appearance of a fatal disease which claimed its victims by the thousands led the governments of Belgium, England, France, Germany and Portugal to appoint special commissions charged with its study. The parasite first discovered by Forde and Dutton, in the blood of a river captain, on the Gambia (1901) was shortly afterwards found in the cerebro-spinal fluid and in the blood of afflicted natives, in Uganda, by the British Sleeping Sickness Commission. Since that time, the *Tr. gambiense* and the disease itself has been the subject of innumerable studies carried on not only in tropical Africa but also in European and American laboratories. The Bulletin of the Sleeping Sickness Bureau which the British Government, through the Royal Society, publishes monthly, is now in its third year of existence. An important function of this Bulletin is to supply careful summaries of all recently published papers dealing with trypanosomiasis of man and animals, and more especially Sleeping Sickness. The prompt and wide publicity thus given to the numerous researches dealing with this and related diseases is of the greatest possible benefit. Facts regarding the distribution of the disease, its mode of transmission, diagnosis, prevention and treatment are of vital importance if the disease is to be effectively controlled.

The mode of transmission of sleeping sickness is one of very general interest and for that reason can be briefly referred to. It has been shown conclusively that it is spread by a biting insect, the tsetse-fly (*Glossina palpalis*). The glossinas are sanguivorous flies and live entirely, it seems, upon the blood of animals. They are known to feed upon crocodiles, birds, wild animals and man. If the disease was exclusively

one of man, and was conveyed by the fly wholly from man to man, then it might be possible to eradicate the disease by removing the natives from the infected territory for a sufficient length of time, that is until the infected flies had died off. Segregation has been practiced on a large scale in Uganda, but the studies of Bruce and his co-workers have shown that the flies caught in places which had not been visited by the natives for two years were still infective. This fact made it quite clear that the trypanosome of sleeping sickness is really a parasite of some wild animal. In other words the wild animals serve as the natural reservoir for the virus. Experiments on antelopes, by Bruce and his co-workers, have shown that these animals can be infected by the tsetse-fly and, that in turn the antelope, though its blood shows no parasite recognizable by direct examination, nevertheless, is capable of infecting clean tsetse-flies. It would seem, therefore, that the antelope or some similar wild animal was the natural carrier of the *Tr. gambiense*. A reasonable proof in support of this view will be furnished when the parasite is actually found in the free roaming wild animals. Koch's belief that the crocodile was such a reservoir has in nowise been confirmed.

The fact that the tsetse-fly does transmit the disease was soon established but it was not clear as to just how this was effected. It was at first believed that the flies were mere passive carriers, and that they carried the parasite directly from the infected animal or man to man. In other words, they were supposed to act like the needle of a syringe, in a purely mechanical way. If this were so, the flies would become cleansed after a few hours, or at most in a day or two. The early observations of Bruce (1895) on the tsetse-fly (*Glossina morsitans*) which transmit a horse disease (nagana) indicated that the fly was a mechanical carrier.

On the other hand, if the ingested trypanosomes underwent development and multiplication in the gut, the fly itself would become infected or diseased and would therefore become an active carrier. As such, it would be able to transmit the disease weeks and even months after the infective feed.

Independent observations made by the British Sleeping Sickness Commission and by Koch (1906) revealed the presence of flagellates in the gut of a large number of captured flies. These flagellates were at once supposed to be developmental forms of *Tr. gambiense* but this was soon shown, by Minchin and by the author, not to be the case. Of the four types of flagellates present in the gut of the flies, to which I called attention, only one seemed to have a possible relation to *Tr. gambiense*. The other types were undoubtedly either natural parasites of the fly or were derived from ingested trypanosomes. The most common type, designated by me as *Tr. Grayi*, was believed by Koch to be of crocodile origin while Minchin considered it to be derived from avian trypanosomes.

The question as to whether the tsetse fly could act as an active carrier was finally settled by Kleine (1909) who demonstrated that flies which had fed upon blood infected with *Tr. brucei*, after a non-infective period of 20 days could transmit the disease. This important fact was soon confirmed by Bruce and his co-workers, as well as by other investigators, and constitutes a distinct achievement. While it is possible for the fly to transmit the disease from animal to animal by interrupted feeding it is now certain that this is not the common, natural way.

The trypanosomes, after being ingested with the blood, slowly adapt themselves to the new environment in the gut, and, in a certain percentage of the flies, eventually multiply and become quite numerous. A period of incubation of from 2 to 3 weeks is necessary to bring about this adaption, and it is an interesting fact, that about this same length of time is necessary to secure the first generation of a culture in a test-tube. It would seem therefore, that, as in the case of the bird trypanosomes, the insect carrier is essentially a culture tube. While recognizing this fact, it should be clearly pointed out that it is not fully established as to just how the parasite leaves the infected fly to reach the wound caused by the bite.

Recent studies go to show that the cause of sleeping sickness (*Tr. gambiense*) is represented by several distinct strains. Thus, the West African form seems to be more easily destroyed by treatment than is the parasite found in Uganda. Another strain has already received a distinctive name (*Tr. rhodesiense*). The existence of such strains or varieties is not surprising for variations, more or less marked, must be expected. We know of such strains in the case of other animal trypanosomes and they have been recognized for some time among the spirochetes, to say nothing of the bacteria proper. An entirely different species of human trypanosome (*Schizotrypanum Cruzi*) has been described by Chagas (1909), in Brazil. This disease, however, has been but imperfectly studied and it will be necessary to await confirmation of the work.

LEISHMANIA.

Closely related to trypanosomes, as regards cultural characteristics, is a group of parasites which has received the generic name of *Leishmania*. Unlike the trypanosomes which freely move about in the blood plasma, the Leishmanias are actually intracellular parasites, more especially of the white blood corpuscles and of endothelial cells. Contrary to the commonly accepted view, these cells instead of devouring and destroying the invading organism become the hosts of the parasites. For that reason the parasites have been called leucocytozoa or phagocytozoa.

To one inclined to search for the origin of organisms it would not be difficult to assume that the ancestral form of the trypanosomes and Leishmanias were intestinal flagellates of insects which differentiated with their adaptation to the vertebrate host. The former becoming the large typical plasma parasites; while the latter, unable to establish themselves in the plasma, were ingested by the leucocytes where in a modified form they were able to live and slowly multiply.

The interest aroused by the discovery of the human trypanosome led Leishman (1903) to publish an observation made two years before regarding the presence of peculiar rounded bodies in the organs of a soldier invalided from his station near Calcutta. The fact that these bodies showed a nucleus and a micro-nucleus, and therefore resembled rounded or degenerated trypanosomes led him to believe that flagellates of this type would be found in fresh blood, or in the fluid obtained by splenic puncture during life.

An examination of such fresh material in Madras failed to demonstrate trypanosomes but did show the presence *intra vitam* of the bodies observed by Leishman. The disease in which this organism is found

is known as Kala-azar, and the parasite (*Leishmania donovani*) is commonly referred to as the "Leishman-Donovan Bodies." In 1908, a similar infection was recognized in young children at Tunis, by C. Nicolle, and has been designated as infantile splenic anaemia. During the past three years this disease has been shown to exist in Italy, Greece, Tripoli, Algiers, etc., and there can be no doubt but that it is of much more frequent occurrence than has been supposed.

Nicolle, unlike the Indian investigators, was able to transfer the infection to dogs by inoculation with suspensions of the diseased organs; and, moreover, he succeeded in cultivating the organism upon blood agar. With such cultures we were able to infect dogs and reproduce the typical disease, thus establishing beyond doubt the relation of the cultural flagellates to the Leishman bodies. Since it had not been possible to inoculate the Indian kala-azar into dogs, or to cultivate the parasite on blood agar, Nicolle assumed, for the time being, that the Tunisian parasite was different and hence proposed to designate it as *Leishmania infantum*. It seems quite reasonable to believe that the failure to cultivate and to infect with the Indian parasite was largely due to faulty method and that in the end the two parasites will be found to be identical. In fact, in his most recent paper on this subject, Nicolle has accepted this view of the unity of the parasites.

A third type of the disease, known as "Oriental sore," "Delhi boil," "Aleppo button," etc., is caused by a similar parasite (*Leishmania tropica*, first discovered by Wright (1903). While the kala-agar (Indian and Tunisian) is almost always fatal, this infection is purely local and recovery is invariably the rule; in this respect there is a marked similarity to the pathogenic and non-pathogenic trypanosomes. The cultivation of this organism has also been realized and the disease has been successfully transmitted to animals. A similar if not identical disease has been observed in Brazil and even at Panama.

The transmission of these diseases, due to Leishmanias, is undoubtedly brought about through the agency of some blood-sucking insect. The fact that the parasite can change from the non-motile intra-cellular form into the actively motile flagellate, in the test-tube, within 36 hours, indicates quite clearly that the parasite must exist outside of the body of man and dog, in the flagellate condition, and that, probably, in the gut of some insect. Recent work seems to indicate that the dog flea is the carrier concerned.

HEMOCYTOZOA.

Following up the views of Schaudinn regarding the relation of the intra-cellular parasites of the owl to trypanosomes, some investigators have endeavored to show that all such parasites were derived from flagellates. Whatever, may have been the origin at some remote time of the intracellular parasites, one thing is certain, namely, that (apart from *Leishmania*) no transformation of flagellates into cytozoa, or *vice versa* has been established.

The researches which revealed the nature of malaria and its mode of transmission are, and ever will remain of commanding interest, marking as they do a most important epoch in man's history. These well-known studies, however, are not as recent as those which are under discussion and hence need not be considered.

Just as the plasma of the blood forms the special habitat for the spirochetes and trypanosomes, so the corpuscles of the blood act the part of hosts for other types of protozoa, collectively designated as *Hemocytozoa*. The organisms thus brought together because of a common habitat may be extremely different in other respects. In a rather rough way, they have been separated into a number of genera, the most important of which is the genus *Plasmodium* which includes the malarial organisms of man and the similar parasites found in the red blood cells of birds, monkeys, bats, etc. These organisms are transmitted by certain mosquitoes, the parasite undergoing in the insect host a complex cycle of development. An enormous amount of work has been done during the past few years on these and the related parasites, such as the Halteridium, Leucocytozoon, Hemogregarina, and Piroplasma. To give an adequate account of these studies would require considerably more time than is available.

ULTRASOMES.

Even a short review of the advances which have been made within recent years in the study of parasites would be incomplete without some reference to the existence of the so-called invisible or filterable organisms. The ordinary bacteria and protozoa are relatively large, and can be seen under the microscope by the trained observer. Their size is such that, as a rule, they will not pass through the porcelain and other filters. For years, it has been customary to speak of bacteria as the smallest of living beings but this is now no longer true. We now know of the existence of living organisms which are smaller than the smallest known bacterial cell; so small, indeed, as to be invisible under the highest powers of the microscope. Because of this fact they are often referred to as ultramicroscopic.

A number of very important human diseases have been shown to be due to organisms of this type. Mention need only be made of Yellow Fever, Acute Anterior Poliomyelitis, Dengue, Papataci Fever, Foot and Mouth Disease, and Rabies. It is quite probable that this list will be extended materially in the near future. Similar diseases are known to exist among animals; chicken pest, hog cholera and pleuro-pneumonia of cattle are examples of this kind. It has been our good fortune to encounter a disease of this nature among out laboratory rats and a brief account of several facts recently ascertained will serve to emphasize the general character of this type of organisms.

The rat ultrasome is invariably fatal to this animal but is without effect in all other laboratory animals. It is present in the blood in large numbers as is indicated by the fact that the injection of a billionth of a cubic centimeter (and at times even less than this amount) of the blood is sufficient to kill a rat. The smallness is demonstrated by the ease with which it passes through the Berkfield, Pasteur-Chamberland and Doulton filters. Indeed, it has been possible to pass it through apparently homogeneous membranes, such as the collodium sac and agar-soaked filters. When submitted to centrifugation at a speed of 8,000 revolutions per minute for 12 hours, even when the serum is diluted with a thousand times its volume of distilled water, the organism is not thrown down.

This rat ultrasome is probably an extreme example of this group, and

it should be stated that there are other viruses which more nearly approach the visible organisms. These facts, however, indicate that there are living particles far beyond our limits of vision. Whether they are to be classed among the bacteria or protozoa, whether some of them even possess cell structure is uncertain and perhaps must remain so.

Ann Arbor, Mich., June, 1911.

RESISTANCE OF TRYPSIN TO HIGH TEMPERATURES.

W. E. FORSYTHE.

Whatever the chemical nature of enzymes may be it is generally accepted that they have little resistance to heat. Trypsin is considered especially sensitive to such thermal action. 55-60° C is generally considered ample to destroy this enzyme when heated in solution. The exact point depending very much upon circumstances as, the preparation and the technic employed. Vernon (4) and Biernacki (1) put such thermal death point for trypsin less than the above while Bayliss & Straling (5), Krukenberg (8), and Roedèr (8) in general consider such temperatures insufficient.

In this laboratory, working with three samples of Grubler's trypsin in 5% glass distilled water solutions, heating up to 80°C was usually necessary to destroy the trypsin action. This temperature was necessary to completely precipitate a proteid that was in these solutions, and thus removed from most solutions heated at 80°C or higher.

The methods employed were various. For temperatures not over 100°C the best results were obtained if the solution was placed in constricted and sealed tubes and then completely submerged in water bath. Then fresh well washed fibrin flakes were added to these solutions after they were put into other tubes and made .3% Na_2CO_3. The digestion was carried out at 35-37°C and observations made qualitatively from time to time.

PROTECTION BY PROTEIDS AND INORGANIC SALTS.

In general it is understood that trypsin may be to some extent protected from acid, alkalie, and heat destruction when mixed with proteids, (6), (1), and inorganic salts (1). Schmidt (7) protected water solutions against the boiling temperature by heating in the presence of peptone, gelatin, and agar. These were among results that caused him to indicate the possibility of sterilizing a solution of this enzyme by heat.

Upon the suggestion of Dr. Novy an attempt was made to duplicate some of these unusual findings. The results were rather unsatisfactory, but the work was limited by an early observation which has since received most attention.

PROTECTION BY COLD TREATMENT.

The fact early encountered in the work was the result of irregularities in the action of trypsin in solution. It was observed that solutions after keeping in the ice box, 0° to 8°C for 24 to 48 hrs. appeared to be more resistant to heat than those freshly prepared. As a result of many variously modified tests on these trypsin samples positive diges-

tions were obtained after heating the cold room treated solutions to the extreme heat of 110°C for 20 min.

Table No. 1 indicates some of the results repeatedly obtained as it includes a few parts of a variously controlled experiment.

TABLE NO. 1.—Exp. No. 3; Test No. 8; Sample B.

Tube.	Treatment of solution.	Heat temperature.	Heat time.	Digestion hours.		
				24.	48.	
5A	Fresh.	110°C	20 Min. .	−	−	
3A	24 hrs. 0°-8°C.	110°C	20 Min ..	±	+	
1A	168 hrs. 0°-8°C	110°C	20 Min...	±	+	
6A	Fresh.	....	....	+	+	Control.
4A..	24 hrs. 0°-8°C.	.. ..	...	+	+	Control.
2A	168 hrs. 0°-8°C	. ...	...	+	+	Control.

The importance of the *cold* and not the *time* element in the above protection is shown by tests such as are indicated by table No. 2.

TABLE NO. 2.—Exp. No. 15. Sample C.

Tube.	Treatment of solutions.	Heating.	Time.	Digestion hours.		
				8.	24.	
1..	4 days at 35°C..	100°C	20 Min..	−	−	
2..	4 days at 23°C	100°C	20 Min...	−	−	
3....	4 days at 0°C...	100°C	20 Min.	±	+	
1A	4 days at 35°C..	....	. . . ..	+	+	Control.
2A	4 days at 23°C	.. ..	.. ... .	+	+	Control.
3A	4 days at 0°C..	....	..... .	+	+	Control.

Thus we see that the room temperature and above offer little resistance to the solutions, although certain results show that the room temperature protects more nearly than the warmer one.

STERILE DIGESTION.

In all the tests where ox-fibrin was used for the digestion the question of the possible bacterial action was never eliminated, although the tests were at all times comparable. Thus it was attempted to obtain digestions under sterile conditions with a solution that had been sterilized by heat.

Table No. 3 shows some of the results where well washed sterile fibrin from rabbits blood was used to test the digestive power of solutions after various heatings.

TABLE NO. 3.—Exp. No. 22. Tests Nos. 2 and 3. Sample C.

Test.	Tube.	Treatment of solution.	Heating temperature.	Heating time.	Digestion hours. 13.	Digestion hours. 24.	Culture beef tea.	
3	1	4 days 0° to 8°C	110°C	20 Min.	–	–	. . .	
	2	1 day 0°- 8°C	110°C	20 Min.	–	–	. . . .	
	3	Fresh	110°C	20 Min.	–	–	. . . . .	
2	2	6 days 0°-8°C	110°C	15 Min.	–	+	–	
	2A	1 day 0°-8°C	110°C	15 Min.	–	+	–	
	2B	Fresh	110°C	15 Min.	–	–	. . .	
3	4	4 days 0°-8°	110°C	10 Min.	+	+	–	
	5	1 day 0°-8°	110°C	10 Min.	+	+	–	
	6	Fresh	110°C	10 Min.	–	–	+	
3	7	4 days 0°-8°C	100°C	20 Min.	+	+	. .	
	8	1 day 0°-8°C	100°C	20 Min.	+	+	. .	
	9	Fresh	100°C	20 Min.	–	–	. . . .	
2	3A	Fresh	. . .	. . .	+	+	. . . . .	Control.
	4	6 days 0°-8°C	. . .	. . .	+	+	. . . . .	Control.
	4B	1 day 0°-8°C	. . .	. . .	+	+	. . . .	Control.
3	13	Fresh	. . .	. . .	+	+	. . . . . .	Control.

Attempts to sterilize a solution of the exzyme by fractional heating at lower temperatures resulted in destroying the action usually at the second heating.

It was suggested by Dr. Novy that it might be possible to restore the vitality to a solution of the enzyme that had been killed in fresh solution, if subsequently kept in the cold for varying lengths of time. Repeated attempts in this connection show that it probably cannot be done so simply.

A limited number of tests seemed to indicate that the above cold room treatment does not afford such protection against the action of heat on pepsin.

CONCLUSIONS.

1. Trypsin in our purest solutions, fresh, is completely destroyed by 80°C, at the most.
2. Proteids and inorganic salts are known to protect this enzyme against such heat destruction.
3. It is believed to have been shown in this laboratory that cold, 0° to 8°C, will protect at least some samples of the enzyme in solution against extreme heat 110°C for a time of 20 min.

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Laboratory of Physiological Chemistry, University of Michigan, Ann Arbor, April, 1911.

SOIL AND SOIL PROBLEMS FROM THE STANDPOINT OF PHYSICIST.

J. A. JEFFERY.

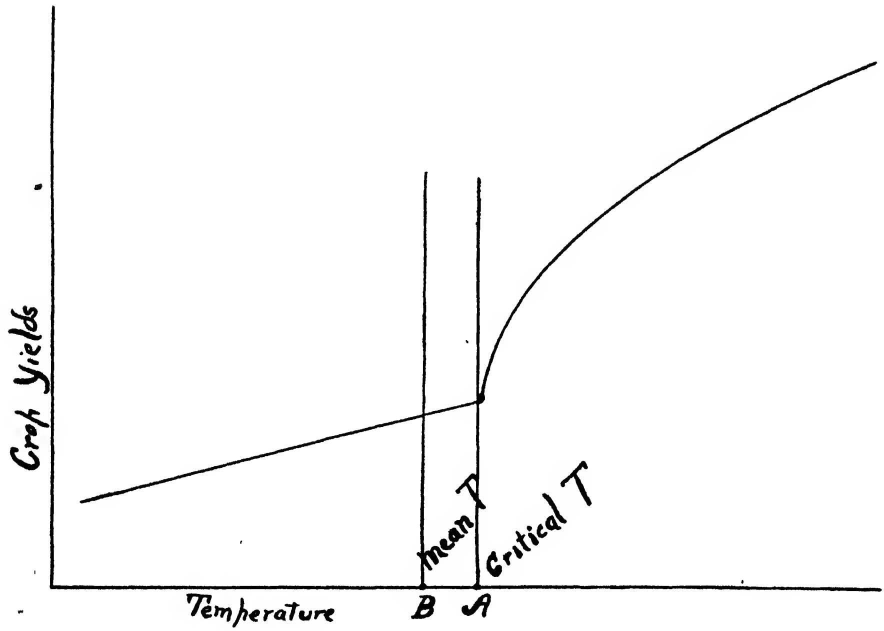


FIG. 1.

So long as soils produce moderate to large crop yields, their productiveness does not arouse much concern, it is not taken seriously. When the yields reach a point so low as to be unprofitable or but moderately profitable, the question "why" is asked. Not long ago this question was thought not so hard to answer. It was generally conceded that the supply of plant food was being exhausted. The remedy was as simple and about as correct as the answer:—The supply should be replenished.

For a time the replenishing worked, and it does yet under certain conditions. Under other conditions it does not. The result is that other "whys" are introduced until at the present time the whole thing is given another name. It is a *soil problem*, and a many sided one.

It was thought at one time that the solution of the problem lay with the chemist, but he failed to produce a satisfactory solution, and as the problem is further studied it is suspected that the botanist, the bacteriologist, the soil physicist and the practical crop and fruit man may each be required to assist not only to determine the causes, but also to decide upon the theory and the facts of the remedy.

Two soils are here offered by way of illustrating the reasons or some of the reasons at least for the foregoing conclusions.

These two soils were taken from adjacent fields. In appearance they are very similar—practically identical. They did not appear so 18 years ago: That year the soil numbered 1 produced 42 bushels of wheat per acre, last year it produced 18 bushels per acre. Eighteen years ago the soil numbered 2 produced 12 bushels of wheat per acre, last year it produced 36 bushels per acre. Eighteen years ago the soil numbered 2 was called a "blow" sand. At the present time it does not blow. Its moisture condition does not permit it. When the present owner purchased this land 19 years ago he was laughed at for his alleged folly. He had faith in the soil however, and in his ability to make it a profitable soil and his faith has been abundantly rewarded.

The transformation has been brought about without the use of mineral fertilizers. The owner has read, observed and thought.

He has practiced care in the selection and use of tools.

He has followed a fairly careful rotation of crops—one in which clover formed an important part.

He has grown one "money crop" each year—wheat, or potatoes or beans.

He has built up a dairy herd in addition to keeping other live stock, and has exercised fair care in husbanding and applying the manures produced on the farm.

In other words he has followed a fairly rational system of soil management (practice).

The farm from which the soil numbered 1 was taken has been rented during the greater part of the period. Further comment is hardly necessary.

Two important facts are before us. First: The larger part of Michigan soils are producing abnormally low yields and in not a few cases negatively profitable yields. Second: In a goodly number of cases soils producing very low and even unprofitable yields have been transformed into highly productive soils, and that without the addition of mineral fertilizers. In general the transformation has been accomplished by means similar to those applied to the soil numbered 2 above.

We ask then what are the causes of this lowering of yields?

Are they chemical, physical or biological, and whatever the direct cause, may it be due indirectly, the soil physicist will ask, to the failure of the soil to function normally physically and if so how great is the departure from normal?

Is the departure measurable?

If measureable, how far does the departure affect
chemical changes,
the abundance and activity of life forms,
solutions,
surface tension,
osmosis,
transpiration, and
deposits and retention of the by-products of plants
and how far do any of these become causes as well as effects?

The fundamentals to crop production so far as the soil is concerned are:

Proper temperature
Proper moisture
Proper ventilation.

In this soil investigation work the Soils Department is attempting to make a study of

Temperature

As modified by other conditions { Physical
Etc.

As a modifier of other conditions { Physical
Etc.

As an index of other { conditions
activities, { Physical
Etc.

(The relations other than physical are to be studied co-operatively)

Some of the questions presenting themselves are:

I. What is the normal temperature for the different types of Michigan soils, (under normal conditions)?

II. How far does any individual of a type, as the soil numbered 2, fall below normal?

III. How far may proper farm practice raise the temperature toward normal or above normal, which may be desirable,—is desirable in most cases?

IV. How far may such rise in soil temperature affect crop production?

A good deal has been discovered and written already concerning soil temperatures and it may be questioned whether this data already found might not be used in this experiment.

It is a fact which is coming more and more to be appreciated that the facts apparently controlling the temperature in one soil may not be effective in the same direction and to the same degree in another soil. It is true also that much of the data already found may have been improperly interpreted and even improperly presented in our Agricultural literature.

It is commonly set forth that the application of manures to the soil has the effect of raising the temperature and this rise of temperature is credited quite largely by some writers to the fermentations taking place in the manure thus added. Experiments conducted at this station show that an application of ten tons of manure per acre worked to a depth of six inches into the soil *when apparently no other influences are at work* results in a temperature rise of about 0.15 degrees F. In sunshiny weather the temperature of the soil receiving this ten tons of manure per acre is raised over two degrees, apparently because of the increased capacity of the soil to absorb the sun's heat. For the reasons named above, we deem it advisable to make a careful study of the details of soil temperature.

A very important question that has suggested itself, is the possibility of what might be called a critical soil temperature, beyond which the result in crop yield may increase very rapidly. It must be admitted that the question strictly speaking is but a hypothetical one and yet there is ground for such question. Fig. 1 illustrates the idea. The horizontal dimension represents temperature, while the perpendicular

dimension represents crop yield. A. represents the theoretical critical temperature. The curve of yield which may be a straight line to the left of the critical temperature becomes a rapidly ascending curve beyond the point A. If B. the mean temperature of the soils stand fairly close to the critical temperature it may be possible by proper methods of soil management to raise the mean temperature beyond the critical point. The benefits are represented by the rapidly ascending curve. There are numerous means at hand by which the farmer may materially improve the temperature of his soil.

If there be such a critical temperature it may be that this critical temperature will prove an average mean. If however, it should prove to be a mean of maximum temperatures the question becomes a more important one. It is barely possible this critical temperature may prove to be the extreme maximum, that is the highest temperature that is reached at any time. Then the question becomes even more important yet.

If there be such a critical temperature it makes little difference whether it be a direct cause or whether it be an indirect cause acting through one to a dozen phenomena.

Michigan Agricultural College, East Lansing, Mich., April, 1911.

SOIL AND SOIL PROBLEMS FROM THE STANDPOINT OF THE CHEMIST.

A. J. PATTEN.

From the standpoint of chemistry the soil is a conglomerate mixture of definite inorganic compounds resulting from the disintegration of rocks, together with the organic remains of plant and animal life in various stages of decomposition, water and gases.

It was early supposed that all the changes taking place in the soil were chemical in their nature, it was also believed that all the phenomena of plant growth were essentially chemical. The following quotation is taken from Johnston's Agricultural Chemistry: "The art of culture indeed is almost entirely a chemical art, since nearly all its processes are to be explained only on chemical principles. If you add lime or gypsum to your land, you introduce new chemical agents. If you irrigate your meadows, you must demand a reason from the chemist for the abundant growth of grass which follows." Thus, according to Johnston the knowledge of soil conditions was only limited by the lack of knowledge of chemistry.

About the middle of the nineteenth century Liebig formulated his theory which he expressed in the following four laws:

First—"A soil can be termed fertile only when it contains all the materials requisite for the nutrition of plants, in the required quantities and in the proper form."

Second—"With every crop, a portion of these ingredients is removed. A part of this portion is again added from the inexhaustible store of the atmosphere; another part, however, is lost forever if not replaced by man."

Third—"The fertility of the soil remains unchanged if all the ingredients of a crop are given back to the land. Such a restitution is effected by manure."

Fourth—"The manure produced in the course of husbandry is not sufficient to maintain permanently the fertility of a farm. It lacks the constituents which are annually exported in the shape of grain, hay, milk and live stock."

The promulgation of this theory naturally placed an added emphasis on the value of the inorganic plant-food constituents and it was believed that with the results of a chemical analysis of a soil it would be possible to determine its crop producing power and likewise its fertilizer requirements. However, it soon became evident to agricultural chemists that there was no definite relationship between the productive capacity of a soil and its content of nitrogen, phosphoric acid and potash.

Many people, however, today believe that the chemist needs only to make an analysis of a soil in order to advise the proper kinds and amounts of fertilizer to be used and I fear that this idea is being encouraged by some soil investigators.

The amount of so-called plant-food in the soil is only one of the factors

governing its productivity, other factors are organic matter, moisture, drainage, cultivation, climatic conditions, etc. Each of these factors is as important as the amount of plant-food, because each has a determining influence upon the crop production and also upon the availability of the plant-food in the soil.

Availability is a convenient term which the soil investigator has used very largely in the past and is using today for describing a condition of things about which we know scarcely anything. We say that the plant-food must be available before it can be taken up by the plants. The truth of the statement will in all probability never be questioned. But the vital point is, what constitutes availability or in other words in what form must the plant-food be before it can be taken up by plants?

The one requirement is, that it must be in solution in the soil water. The soil solution, however, is not a simple one, but, on the other hand is very complex and is influenced by many factors. These many factors are so closely inter-related that any slight change in any one of them is sure to change this relationship and it is impossible to predict, at least with our present knowledge, what influence the changing of any of these factors may have upon the composition of the soil solution. Many attempts have been made to extract the soil solution as it exists in the soil but the attempts have not been generally successful owing to mechanical difficulties. It is probably true, however, that the composition of the solution would not be the same in any two soils in respect to all conditions and it is also quite certain that the composition of the solution in any given soil changes from day to day within certain narrow limits.

Many methods have been proposed for determining the availability of the inorganic plant-food in the soil. These methods have mostly been based upon the relationship between the amount of the inorganic plant-food constituents extracted from the soil by the solvent medium and that taken from the soil by the crop. Maxwell proposed a 1% solution of aspartic acid on the ground that the organic acids of the soil are amino acids and that they influence the availability of the inorganic constituents. Dyer recommended the use of 1% citric acid because he supposed it bore a near resemblance to the methods of solution of plant-food in contact with the rootlets of plants. Moore of the Bureau of Chemistry after several years of experimentation proposed a solution of HCl of N/200 strength.

Many other methods, too numerous to mention, have been proposed. None of them, however, had any sound scientific basis for their acceptance, but were proposed because those who stood sponsor for them observed that with one particular crop grown upon one particular soil there was a relationship between the amount of plant-food extracted by the particular solvent medium and that removed by the crop.

All attempts to adapt these methods for universal application have resulted in failure and when we consider the variation in soils and the great difference in the feeding powers of different crops, the variation in climatic conditions, seasons, drainage, cultivation, etc., it is extremely doubtful if any arbitrary method will ever be devised that may be relied upon to determine the available plant food in all soils.

Although a large part of all the known elements are found in soils, only about 14 are vitally connected with the living plant and it is the

general belief today that only three and at most four of these, nitrogen, phosphorus, potassium and calcium need demand the serious attention of the agriculturist. The amounts of phosphorus, potassium and calcium in virgin soils depends largely upon the composition of the rocks from which they originated. The amount of these elements in cultivated soils depends also upon the manner in which the soils have been handled.

The nitrogen has practically all been introduced into soils since their formation and it is extremely fortunate that this most expensive form of plant-food may be, in a great measure, supplied to the soil by a due attention to the practice of crop rotation. It was originally supposed that only the inorganic forms of nitrogen, phosphorus and potassium could serve as plant-food and many attempts have been made to classify soils as good or poor on the basis of their content of these elements. Maercker of the Halle Station, Germany, has made the following classifications:

Grade of Soil.	Potash.	Phosphoric Acid.	Lime.		Total N.
			Clay Soil.	Sandy Soil.	
Poor	Below 0.05	Below 0.05	Below 0.10	Below 0.05	Below 0 05
Medium	0.05—0.15	0.05—0.10	0.10—0.25	0.05—0.15	0.05—0.10
Normal	0.15—0 25	0.10—0.15	0.25—0.50	0.15—0 20	0 10—0 15
Good	0.25—0.40	0.15—0.25	0.50—1.00	0 20—0.30	0 15—0 25
Rich	Above 0.40	Above 0 25	Above 1.00	Above 0.30	Above 0.25

Other investigators, notably Hilgard, have made similar attempts to classify soils but there is no unity of opinion on this point. It is not at all strange that there should be this wide difference when we consider that the amount of the so-called plant-food is only one of the many factors governing the productive capacity of the soil—other factors are drainage, cultivation, climatic conditions, seed selection, etc.

Although it has long been recognized that organic matter is a great asset to the soil but little has been definitely learned in regard to its nature and composition. There is a tendency on the part of most soil experimenters to associate soil organic matter with the term humus. Many consider them to be synonymous, others consider humus to be composed of definite compounds produced by the decomposition of organic matter and that there might be organic matter present that had not yet reached the state of humus. At the present time the term humus is generally used to designate the product obtained by treating an alkaline extract of a soil with an acid.

As early as 1844 Mülder made an extensive study of the organic matter of soils and claimed to have isolated seven distinct compounds to which he gave the following names: crenic acid, apocrenic acid, geic acid, humic acid and humin, ulmic acid and ulmin. He also gave to these bodies definite chemical formulae. A little later Grandeau developed his method for separating humus which is essentially the one in use today.

As the number of investigators on the subject of humus and organic matter increased, more or less controversy arose as to the composition of some of these supposed definite compounds. Different investigators

could not agree upon the composition of humic acid obtained from soil nor could the same composition be obtained for humic acid derived from different materials. Later a controversy arose over the question as to whether nitrogen was a constituent part of the humus or not. Some claimed that it was organically combined, while others claimed that the nitrogen was present as ammonium salts.

Without going farther into a review of the literature on this point it will be seen that the one thing which characterized the work of the early investigators was the lack of anything like concordant results. In fact the same lack of definite results has characterized the work of all investigators down to the present time who have followed in the footsteps of the early workers in their attempts to throw light upon this most interesting and difficult problem. Consequently there seems to be no valid reason why we should continue to use a method for determining humus, which, we must admit, removes not one compound but a mass of organic compounds about which we are only beginning to learn the least little bit. And furthermore it would seem to the writer that it would be a step in advance if we would discontinue the use of the term humus altogether and confine ourselves to the more comprehensive term—organic matter.

During the past few years much good work of a purely scientific character has been done on the organic matter of soils. Shorey, now of the Bureau of Soils of the United States Department of Agriculture was the first to isolate a definite crystalline compound from soil. This he identified as picoline carboxylic acid. Since then Schreiner and his associates have isolated several organic compounds, many of which have proved to be more or less toxic to wheat seedlings. Nearly all of the compounds isolated by these workers have been free from nitrogen.

Nitrogen which is the most costly form of plant-food we have to consider, is present in the soil almost entirely in combination with organic matter and probably very largely in the form of protein compounds. If this is true, then the breaking down of the nitrogen compounds in the soil is largely one of proteolysis and one should expect to find many of the same compounds in the soil as results from the hydrolysis of protein compounds in the laboratory.

Suzuki digested humus with hydrochloric acid and from the extract was able to isolate the following substances, long recognized to be decomposition products of protein: Alanin, Leucin, Aminovalerianic acid, Prolin, Aspartic acid together with traces of Glutamic acid, Tyrosin and Histidin.

Three years ago Jodidi working in the chemical laboratory of the Michigan Experiment Station began a study of the organic nitrogen compounds in peat soils and from his work concluded that from two-thirds to three-fourths of the nitrogen extracted by boiling acids is in the form of monoamino compounds, about one-fourth in the form of amids and the rest is in the form of diamino compounds.

Jodidi did not succeed in isolating any individual compounds although he was led to believe that tyrosine was present in traces.

Mr. Robinson continuing the work of Jodidi has recently succeeded in isolating leucin and isoleucin from peat soils after boiling with acids. Also, by adapting to his conditions the method for amino nitrogen recently revived by Van Slyke, he has been able to determine with con-

siderable accuracy the amount of nitrogen in these forms. In the samples of peat already worked with, the amount of amino nitrogen after boiling with acid has been from 30-35% of the total nitrogen. Only traces of amino nitrogen are found in peat as such.

These compounds necessarily occur in soils in small quantities, and their separation is accomplished only after the most careful and painstaking work. But it is confidently expected that now since the way has been fairly well paved more investigators will be tempted to enter this field of research and more of these compounds will be isolated from soils.

Certain it is that with a more complete knowledge of the composition of the organic matter of soils one will be able to predict more definitely in regard to the possible availability of some of the plant-food elements in combination with it.

The relation of the soil phosphorus to the organic matter is perhaps less understood today than is the case with nitrogen. There has been a great diversity of opinion as to the existence even of phosphorus in combination with organic matter. As early as 1844 Mülder observed that the organic matter was not readily freed from phosphorus. Grandeau believed that the phosphorus associated with the extracted *matiere noire* to be an index of the fertility of the soil. Eichorn concluded that the phosphorus does not form organic combination. Some experimenters believed that the phosphorus was held in the organic matter by absorption. Van Bemmelen supported this theory and he suggested that a part of the phosphorus occurred in the form of a "colloidal humus-silicate complex."

Schmoeger reviewing the work of his predecessors concluded that the phosphorus did not exist as absorbed phosphorus but that it was present in organic combination. He found lecithin to be present in traces and was led to believe that nuclein or some closely allied bodies were present. Asô confirmed in a general way, the results obtained by Schmoeger. He drew the following conclusions:

1. "Phosphorus exists in the soil as inorganic and organic compounds."
2. "The organic phosphorus materials is principally nuclein with a small part of lecithin."
3. Ignition rendered the phosphorus in organic combination available."

More recently Schreiner and Shorey have demonstrated the fact that phosphorus does exist in the soil in organic combination by isolating several compounds known to be decomposition products of nucleo-proteids. Beyond the fact that the presence of organic matter in the soil improves its combination and also increases its productive capacity we know but little of the value of any of these specific compounds as possible sources of plant food. We know there are some organic compounds in the soil that are harmful and we need to know more in regard to the most practical means of counteracting them.

The manner of conducting fertilizer tests by measuring the crop produced has failed to materially increase our knowledge of soil conditions and it is now quite generally recognized that it is unsafe to draw general conclusions from results based on such experiments. If we accept the dynamic theory of soils, that is, that they are continually changing and that no two soils are alike, we must inevitably come to this conclusion.

These experiments have, however, served a purpose, in that they have taught us the direction in which soil investigations of the future must lead. The introduction of a chemical substance into the soil changes the condition, not only in respect to the material added but to those already present. It also may and probably does affect the physical and biological condition as well as the chemical.

The method practiced by some experimenters of analyzing a soil sample representing the first eight or ten inches and from the results estimating the number of bushels of grain or the number of years that the soil will produce a certain sized grain crop before it becomes exhausted is unscientific and unsound. The time is now ripe when we should attack these problems in a truly scientific way.

While of course greater productive capacity is the ultimate aim of the soil investigator he should seek to find out and understand the changes taking place in the soil that accompany greater production.

Michigan Agricultural College, East Lansing, Mich., April, 1911.

SOIL AND SOIL PROBLEMS FROM THE STANDPOINT OF THE MICROBIOLOGIST.

OTTO RAHN.

Soil is to the physicist a mixture of particles of various sizes, as gravel, coarse sand, fine sand, silt, and clay. These particles have certain physical qualities, as absorption, heat conduction, water capacity, and pore space. The physical qualities of a soil are determined by the amounts and kinds of particles constituting it.

The chemist looks at soil problems in a different way. Soil appears to him as a mixture of soluble and insoluble compounds, of organic and inorganic matter. Some of the soil constituents are known to be plant foods, and to them the special attention of the chemist is directed.

To the microbiologist, soil is a medium for the development of a large variety of microörganisms. The domain of the soil bacteriologist is increasing rapidly, and the term bacteriology seems hardly broad enough for a science that includes, besides the bacteria, yeasts and molds, even the single-celled animals,—protozoa.

In order to discuss the soil problems from the standpoint of the microbiologist, it seems advisable to first state briefly the facts that are already established in soil bacteriology. Like the chemist and the physicist, the microbiologist studies soil problems ultimately from the viewpoint of soil fertility or crop production. From this viewpoint, microörganisms may be divided into those that are beneficial and into those injurious to crops. Of course, this distinction is not an absolute one, but it is helpful in classifying soil microörganisms according to their significance.

Microörganisms can be useful to plants in various ways, either directly by symbiosis, or indirectly by preparing plant food. Symbiosis of higher plants with microörganisms is limited practically to the roots, but there it is a very common occurrence. The root-tips of the evergreens and of many other forest trees show quite regularly a growth of mold mycelium which is called mycorrhiza. Many other plants show mycorrhiza growth frequently, while with some it occurs only very rarely or not at all. There is no doubt that the mycorrhiza is of benefit to the plants, though the relations between mold and host are not entirely explained as yet. It seems that the mold helps the plant to obtain food, either mineral matter or nitrogenous compounds. Perhaps, they fulfill different purposes in different plants.

Much attention has been given to another case of symbiosis, namely that of legumes with Pseudomonas radicicola, the bacterium of the root nodules. This symbiosis is so well understood that pure cultures of such bacteria are now grown commercially for inoculating the seed. It is at present the only case of a direct application of soil bacteriology. The subject is so generally known that it would be wasted time to discuss any details before this audience.

Far more important than the above mentioned direct relations between plants and microörganisms are the indirect relations, especially the preparation of plant food. Most soils contain plenty of plant food, but it is largely in a form unavailable to plants. Microörganisms attack and decompose many of these compounds and especially nitrogenous compounds are made available almost exclusively by microörganisms. Thus, plant growth depends upon microbial activity in the soil.

Most attention has been paid to the changes in nitrogenous matter in soils. The nitrogen comes largely from dead leaves, plant roots, excreta, and remains of animals. These compounds are not directly assimilated by plants. They are readily decomposed by bacteria which break up the large molecules into smaller and smaller ones, until finally the nitrogen is in the simple form of ammonia. This may be assimilated by many plants, many, however, prefer nitrates, and they are accommodated by the nitrate-forming bacteria which oxidize ammonia to nitric acid. All of this microbial activity is named briefly "mineralization." The organic matter is, by the exclusive activity of microörganisms, changed to mineral compounds which alone can be used by plants.

But the activity of soil organisms is not limited to the mineralization of organic matter. They also increase the nitrogen content of soils. Two groups of bacteria, the Azotobacter and the Clostridium are known to assimilate nitrogen gas from the air in order to build up their own protoplasm. It is believed that these organisms are necessary to keep constant the nitrogen content of soils which would otherwise be decreased continually by crops, seepage, and denitrification.

The decomposition of nitrogen-free organic matter is also of considerable influence upon the availability of plant food. Cellulose, starch, sugars and similar constituents of the plants are transformed by microörganisms to organic acids and carbonic acid, which will act upon insoluble minerals as calcium phosphate or magnesium carbonate. Insoluble plant food thus becomes available to plants.

A very important product of the decomposition of organic matter has not been mentioned as yet, that is the humus. Very little is known about humus formation and it is mentioned here only because it is certain that humus is formed by microörganisms. How this is done and which microörganisms are essential is not known.

Bacteria are further involved in the oxidations of hydrogen sulphide and of sulphuric acid. Iron compounds are also occasionally changed by microörganisms.

So far, only the beneficial organisms have been mentioned. They constitute by far the majority of soil organisms. But there are also harmful organisms in soil which injure crops either directly or indirectly. Direct injury is caused by all organisms of plant diseases. The rot of vegetables, the potato blight are a few examples of diseases caused by soil organisms.

The indirect injuries to crops caused by microörganisms are in connection with plant food. One group was much feared some time ago, namely the denitrifying bacteria which decompose the nitrates of the soil to nitrogen gas. Such denitrification means a direct loss of nitrogen to the field, but it is known now that it is rather unusual in a well ventilated soil. Another group of harmful organisms are the protozoa,

which prey upon the essential soil bacteria reducing their numbers and consequently soil fertility.

This is, briefly told, a bacteriologist's conception of soil. The object of this paper was to discuss soil problems rather than facts. It is, of course, impossible to enumerate in detail all the many points of interest in soil bacteriology. I shall try to present the most prominent problems which demand immediate attention. This introduces a personal element into the discussion, since not all bacteriologists value the same problems alike. If I speak of important problems, I mean those that are considered to be of vital interest by the laboratory which I have the honor to represent.

A problem that is at present taken up from different sides is that of the humus. The formation of humus has been studied very little, despite its significance, because of the insufficient chemical technique of its analysis. Efforts have been made recently by the Bureau of Soils to obtain a more definite idea of at least some of the many humous bodies, and it can be hoped that before very long humus will be known as a fairly well defined group of organic compounds. The bacteriologist's task is to find the organisms that form humus, and to study their habits and their food requirements. This knowledge will enable us to increase humus formation where it seems necessary and to prevent it, when desirable. The humus problem also includes the destruction. The organisms breaking down humous compounds to ammonia are very important because while not available itself, humus yields decomposition products which are the most valuable plant food, namely ammonia and nitrates. By obtaining a perfect knowledge of the humus-forming and the humus-destroying organisms, we gain control of the humus content in soil.

The peat problem, or more definitely the use of peat as farm soil or as fertilizer is nothing but a side line of the great humus problem. Though there is undoubtedly a great difference between peat and humus, it seems quite probable that the solution of one problem will make the solution of the other an easy task.

Another problem is the constancy of the number of bacteria in soils. This factor may not seem very important to the superficial observer, but it has doubtless close relations to soil fertility. In decaying organic matter, in fermenting liquids, in sewage, and in milk the number of microörganisms will first increase rapidly, then decrease and in a comparatively short time most of the organisms are dead. In a given soil the number of bacteria is practically constant. Slight fluctuations are caused by seasonal influences, by rain and drought, by fertilizers, but the soil soon regains its original number of microörganisms. The old explanation of the constancy as an equilibrium established between the various kinds of microörganisms is not satisfactory. If such an equilibrium were possible at all, it would be found in liquids too. But that is not the case. There may be an equilibrium between bacteria and protozoa, but we have no accurate knowledge as yet of soil protozoology. The constancy of the bacterial flora in soil is very important because it renders possible the immediate decomposition of organic matter entering the soil. In solution, where the organisms die after having acted for a short time, the decomposition soon comes to a standstill. In soil this does not seem to be so, at least, the limit is much wider. The

faster and more complete decomposition in soil cannot be explained by drainage water, removing the harmful products and thus giving bacteria a new chance for activity. Drainage water contains very little organic matter which is of a nature that it could not possibly cause any retardation of microbial action.

This leads to another problem which is perhaps the most prominent one of today, namely the difference of microbial action in soil and in solution. It seems strange that until a few years ago soil bacteriologists paid no attention whatever to the physical structure of soil and carried on all experiments in solution. The dairy bacteriologist grows his organisms on milk or milk products, the veterinary bacteriologist grows bacteria for experimental purposes in the animal body, while the soil bacteriologist does not use soil as a basis for his soil experiments, but meat media and occasionally soil extract. It is very true that there is not much difference chemically between the so-called soil solution which is the natural habitat of soil bacteria and between a soil extract. Not the chemical qualities, nor the amount of food make the great difference between soil and soil solution, but the physical nature of the two. Bacteria live only in liquids. In soils, the liquid is spread in a thin film over all the finest soil particles, and thus the surface is many hundred times enlarged. Doubtless, other soil qualities, like absorption, influence microbial development, but no other factor has such an enormous influence as the exposure of a large surface of liquid to the air in a well-aerated soil. The abundant supply of oxygen is a great stimulus for aerobic bacteria, while anaerobic organisms are decidely suppressed. This can be illustrated by a few experiments in which quartz sand has been used instead of soil in order to eliminate the possible influences from any organic or inorganic soil compounds. A peptone solution was sterilized in a flask and inoculated with a bacterium that formed ammonia from peptone. The same amount of the same solution was mixed with some pure sand, sterilized and inoculated with the same pure culture. After 7 days, ammonia was determined in both cultures, and the sand culture had formed three times more ammonia than the ordinary liquid culture from the same amount of peptone. With two other bacteria, five times and eight times more ammonia was formed in the sand cultures. Evidently these bacteria required plenty of oxygen, since the large supply of air caused an increase of ammonia production of 200 to 700%. A similar experiment was carried on with the nitrogen-fixing Azotobacter, which gave in sugar solution 4.2 mgs., in sugar solution plus sand 35.0 mgs. of nitrogen, the increase caused by sand being 720%. While aerobic bacteria are thus stimulated by the change from liquids to soil, anaerobic organisms are retarded in their development. Bacterium lactis acidi was found to make only about half as much acid in milk, if quartz sand was added to the milk. Similar is the experience with denitrifying bacteria which were feared so much because they destroy nitrates. They are feared no more, for the experiments leading to their discovery were not properly conducted. They are found in most soils and they will destroy nitrate if the soil is submerged in a solution, but they will not attack nitrates at all in a well-aerated soil. Koch and Pettit showed recently that in soil with a fair moisture content, nitrates are not destroyed because the

oxygen from the air is more readily used by the organisms than the oxygen from the nitrate.

These examples will suffice to emphasize the previous statement, that soil problems must be studied in soil and not in liquid media. Since the development of anaerobic bacteria of the soil is greatly increased in solutions, while aerobic organisms are suppressed, it is obvious that changes taking place in solutions allow of no conclusions whatever in regard to changes in soil. We must necessarily expect erroneous and even contradictory results if we neglect variations of 700%. Strange to say, bacteriologists have, until quite recently, paid no attention to this difference. This serious error has been made for more than ten years, and a large amount of work done in this period is probably wasted, since we do not dare to bring the results obtained into any relation with soil problems.

I have emphasized this problem of the "soil as a culture medium" for two reasons. The one is that our laboratory is dealing with this special problem, the other is the urgent need of this work. How can we expect to make progress in soil bacteriology if we neglect factors of the most vital importance for microbial development?

Soil is such a complex mass of organic and inorganic, soluble and insoluble compounds, containing so many different organisms that we cannot possibly oversee all the changes taking place at once. It will be absolutely necessary to reduce the number of unknown factors in soil. It will become necessary to study the development of pure cultures in soil before we can think of dealing with the natural microbial flora and fauna of soils. It will require a large amount of careful and possibly discouraging work to study the peculiarities of soil as a culture medium, but it offers a chance for fundamental, and, I dare say, classical work in soil bacteriology.

Processes other than aeration will probably play a rôle in the microbial development in soil, since it is believed by some chemists that even chemical reactions are different in soil from solutions.

Cameron stated last year (Journal of Physical Chemistry, Vol. 14, p. 402 (1910) ......"We should expect that many reactions would take place quite differently in the soil from the way they would in a beaker or flask. This fact has been generally overlooked or ignored and is probably the explanation of many of the apparently anomalous results hitherto reported in chemical investigations of soils. Enough is known to justify the statement that the chemistry of the soil need not be and probably is not, the chemistry of the beaker."

And still, another factor must be considered as possibly influencing microbial development in natural soils. The publications of the Bureau of Soils have demonstrated that there are organic compounds in soil which retard plant growth. The same or similar compounds may retard bacterial growth. Investigations have never been made along these lines, but the possibility must be considered.

One other problem must be mentioned here which has been considered so little as yet that we cannot even say whether or not it is important to soil fertility. It is the relation of microörganisms to the physical structure of soils. The formation or destruction of humus will certainly influence the physical qualities of soils. But even aside from that, soil is changed physically by microörganisms. A root, a leaf, a piece of straw in soil will decay and the space previously occupied by

organic matter is later an air space, a channel for ventilation. The oxidation of soluble ferrous salts to insoluble ferric salts is apt to change the structure of soils, and so does the solution of insoluble phosphates and carbonates by acids formed by microörganisms. There must be considered further the mycelial growth of molds, and possibly the formation of slime by bacteria. The experiences with sand filters indicate the probability of such influences.

These are some of the great problems which seem to our laboratory the must urgent problems of the soil bacteriology of today. There are many other problems waiting for solution, and they may seem more important to other laboratories.

The solution of such problems depends largely upon the development of the technique. The interest of the microbiologist concentrates in the products of microbial metabolism, and the success of determining accurately the character and quantity of the products of any decomposition depends upon the accuracy of the chemical analysis. The difficulty of analyzing the many compounds in soil has already been pointed out by the chemist's paper. Any improvement in the accuracy of chemical analysis will be of benefit to the bacteriologist. The new method of determining very small amounts of nitrogen which has been worked out in recent years by Mitscherlich will no doubt open a new field to soil bacteriology. The method of determining amino-nitrogen in soils which has been worked out by Mr. Robinson, of the chemical department of our experiment station, will be of great value in the bacteriological studies of the decomposition of humus and peat.

But it is not only the *chemical* technique that limits the study of soil bacteriology. The main difficulty lies in the nature of the material we work with, namely the living organisms. While the chemist and physicist have a constant matter with which to work, the bacteriologist deals with organisms that may multiply, or die, or lie dormant, that are influenced by slight changes of temperature, of moisture, of aeration. The variation of organisms under apparently equal conditions causes frequently a greater discrepancy of results than the probable error of chemical analysis. How difficult it is to avoid mistakes is seen in the different growth in soil and solution which was not considered at all important for more than ten years. The problems of soil bacteriology are different from those of dairy bacteriology, and the methods used in the latter cannot be applied directly to the former.

Soil problems require, above all, a careful consideration of soils as a medium for microbial development. The field is too new to permit bold, haphazard experiments. The conquest of such new land often necessitates a retreat on the whole line unless each step is guarded by reliable troops. This had not been the case in soil bacteriology, and the retreat was a hard lesson. Slowly, step by step, we must investigate the character of soils in relation to microbial growth, we must study the mutual relations of the various organisms, and since all bacteriological work is based upon the physiology of microörganisms, great efforts should be made to amplify our knowledge of the physiology of these smallest organisms. The solution of soil problems requires a strictly scientific study of all factors involved. Without such scientific basis, it may be possible after many mistakes to establish a few isolated facts but never a science of soil bacteriology.

East Lansing, Mich., April, 1911.

SOIL AND SOIL PROBLEMS FROM STANDPOINT OF BOTANIST.

W. H. BROWN.

The soil problem from the standpoint of the Botanist or Plant Physiologist may naturally be divided into two parts:

1. The influence of the soil on the plant.
2. The influence of the plant on the soil.

In dealing with the first part of this problem, the methods used by the Plant Physiologist have usually not differed greatly from those employed by the Soil Physicist or Chemist, since they have usually consisted in an attempt to correllate the chemical or physical factors of the soil with either the total or dry weight of the plant produced. This has been largely the result of the fact that plant physiology is a comparatively new science and that certain general relations had to be established before the underlying physiological problems could be attacked. While from a physiological standpoint, such methods could hardly more than scratch the surface they have nevertheless yielded valuable results. For example it has been found that certain elements are necessary for plant life and that the plant can obtain these from certain chemicals and not from others, that some combinations of chemicals are favorable to growth, that a certain texture or water content of the soil is necessary for some plants and that these conditions vary for different species. In much of the work along this line, however, the mistake has been made of dealing with a complex of factors rather than with individual ones, with the result that the experiments could not be repeated or fundamental conclusions, which would serve as a basis for future work, derived from them. For example, the addition of certain things such as fertilizers or organic matter to the soil has often been treated as an experiment with a single factor even though the things added have been complex and have changed the physical and chemical properties of the soil and influenced the microörganisms in it. Even when individual factors have been dealt with, the relation of these to others has frequently been so complex that some factors have either been ignored or overlooked, with the result that later work has proved the first conclusions either inadequate or erroneous. A good example of this is afforded by the non-available water content of the soil which is the water remaining in the soil after the plant has withered and died because it could not obtain sufficient to supply that lost by evaporation, and to maintain life. The amount of this non-available water has been found to vary with different soils and plants and so without taking into consideration the atmospheric conditions it has generally been stated that it is constant for a given soil and plant. Experiments carried on in Arizona have however, shown that similar plants of *Vicia faba* growing in the same soil, would wilt when the soil contained anywhere from 8 to 35% of water, depending upon the amount of evaporation. As will be pointed out later changes in the internal conditions of the plants also affect the amount of non-available water. While it is

thus evident that much of the work that has been done will have to be repeated under more exact experimental control, the realization of the complexity of the problems will do much to remove the present unsatisfactory condition.

But what, after all, is the most unsatisfactory thing from the standpoint of the physiologist is the small amount of work that has been done on the processes of the plant itself. Little is known about the form in which substances enter the plant, and still less about the relation of conditions in the soil to the internal conditions of the plant and of these internal conditions to growth. While these problems are complex, they are by no means hopeless and should be of tremendous importance from both a scientific and practical standpoint. It may not therefore, be out of place here to discuss some of the possibilities.

Since chemical reactions take place more rapidly in a dilute than in a concentrated solution, we would expect growth to be more rapid when the solution in the cell is dilute than when it is concentrated, provided, of course, that the necessary elements are present in sufficient amount. If a submerged plant such as Elodea, is placed in distilled water or in a very dilute solution of nutrient salts where the tendency would be for the salts to diffuse from the plants to the water and thus weaken the solution in the cells, the plant will grow several times more rapidly during the first three days than if it were in ordinary pond water. Rapid growth does not, however, necessarily mean good growth, and in this case, the plant usually dies about the fifth day. Plants growing under arid conditions usually have an extremely slow rate of growth and the concentration of their juices is higher than that of plants growing in moist localities. Likewise when plants that have been growing under moist conditions are subjected to drought, their juices become concentrated and growth is less rapid or may cease altogether. From the above observations, it would seem probable that the degree of concentration of the juices of a plant may markedly affect the rate of growth. The water content of many plants may be reduced 50 per cent. without causing signs of wilting, by decreasing the amount of water in the soil. In this case, there must be a great increase in the concentration of the solution in the plant cells and an increase in the osmotic pressure. This is followed by a great decrease in the amount of water given off by the transpiration of the plant.[1] Plants thus give off and take up less water when growing in a dry soil than when growing in a moist one. The fact that the amount of water in a plant decreases as the soil becomes drier should find a ready application in agriculture in regions where irrigation is practiced, for if the optimum water content of the leaves were once determined, it would be easy to tell when the per cent of water fell below this. This would indicate that it was time to irrigate, and remove all uncertainty. In all probability growing a plant in a concentrated solution would have the same effect in increasing the concentration of the plant juices as growing it in a dry soil, for the amount of salts taken in a plant is not regulated by the amount of water that passes through it but by the relation between the concentration outside and inside the plant, since the salts move by diffusion and this may be independent of the movement of the water.

It is well known that certain plants will not grow in soils in which the water contains a large amount of dissolved salts. When we ask for

an explanation of this, we are confronted by difficulties which can only be solved by a careful study of conditions within the plant. The harmful effect might be due to an increased concentration of the juices of a plant; or possibly changes in permeability; or to an actual harmful effect on the cytoplasm; or to an interference with the working of an enzyme or some other process. The presence of certain salts in solution may either accelerate or greatly retard the action of enzymes and it is very probable that in plants as in animals, the presence of certain salts is useful in accelerating or retarding various processes. Unfortunately, however, we know entirely too little about the condition of substances within the plant. A good example of the importance of changes in the relation between conditions in the soil and in the plant would seem to be afforded by the non-available water content of the soil. During the day, the leaves of plants are manufacturing sugars which increase the concentration and osmotic pressure of the solution in the cells. At night these sugars are used or removed and the concentration and osmotic pressure again decreases. Since water is probably drawn into the cells by osmosis, we would naturally expect that in the middle of a bright day when the osmotic pressure is high, the water would be drawn into and held in the cells of the leaf with greater force than during the night or early morning, or on a dark day, and that therefore, the amount of water in the soil which is not available to the plant would vary with the time of day and kind of day. This has proved to be the case to such an extent that these factors will have to be taken into consideration in all accurate determinations of non-available soil moisture.

Enough has probably been said to point out something of the importance of studying the conditions within the plant in their relations to soil problems. A thorough understanding of this relation would certainly furnish a satisfactory way of handling many practical questions.

The influence of the plant on the soil, like that of the soil to the plant would appear to be a fruitful subject for investigation rather than a field in which a great deal has been accomplished. Substances which are toxic to plants may be formed in soils as the result of the growth of plants, but whether these are usually excretions from the plant or the result of bacterial decomposition of tissues thrown off from the plant, is uncertain. Many plants particularly fungi and insectivorous ones are known to secrete enzymes and other substances so it is entirely possible that plant excretions may play an important role in changing the chemicals of the soil. The growth of roots appears to be accomplished in some cases by a dissolving of mineral substances, but how much of this is due to things outside the plant, such as acids produced by the decay of tissues is also uncertain. The meaning of the oxidizing and reducing power of roots is likewise little understood.

In conclusion the soil problems from the standpoint of the botanist would appear to me to be one on which comparatively little has been accomplished but which offers tremendous possibilities.

Michigan Agricultural College, East Lansing, Mich., April, 1911.

THE THEORY AND PRACTICE OF SOIL MANAGEMENT.

FRANK K. CAMERON.

The watchword of modern industrial efforts is efficiency. Efficiency implies control; control of materials and control of methods. Control in turn implies knowledge and understanding of materials and methods.

We are met here today in symposium to study the problem of efficiency in soil management. It is meet that this should be so, for this is the *place* where labored for many years a Nestor among soil investigators; the scientific public and especially those more immediately concerned with the soil and soil problems have long looked with admiration and for inspiration to the labors of the late Professor Kedzie. The *time* is propitious, for we are now entering an era of scientific discussion following one marred by acrimonies because a theory has been brought into question—a theory which for three-quarters of a century and upwards dominated the thoughts of soil investigators practically to the exclusion of all others. Useful as was this theory and satisfactory for its time, it is now giving way to, or perhaps it would be better to say, being modified by, increasing knowledge and new points of view. The word *symposium* is, in its derivation, suggestive of drinking together, a simile quite apt to this occasion, for the program we have followed today shows that to attain a comprehensive purview of the soil, we must now draw from the founts of many sciences. The work of the physicists, the chemists, the biologists and the geologists is obviously necessary to a knowledge and understanding of soils. Looking further into the larger aspects of the case and the relation of the soil to human progress and welfare, it seems evident that there is no branch of knowledge but what lends itself to or finds itself called upon in soil investigations.

Finally, the *soil* itself is a subject which is not surpassed in interest by any other. It presents to the scientist many complexities, sometimes baffling, but ever interesting, always suggestive of new lines of thought and of original experimentation. To the practical layman it offers, in soil management, a subject rapidly becoming a highly developed art, passing from the avocation of an artisan to the profession ot a highly trained expert. Upon the soil more than upon any one thing depends the material prosperity and happiness of the race, and equally important is its part in determining the development of the spirituality of the race. However facinating the soil may be to the scientific man, and however strong the justification in studying it for its own sake or simply to add to the sum total of human knowledge, and however interesting in its relations to the æsthetic and emotional development of the race—and these views of the subject are well worth considering in an institution of learning—today we are to think of it from another point of view. The labors of our colleagues, who are working upon the soil as chemists, physicists, biologists, geologists, etc., are

justified by the instrumentation they place in our hands for the management, i. e., control and efficiency of the soil as a source of food.

The great fundamental problem of agriculture is crop production. Efficiency in crop production is not always recognized, nor even what efficiency means. There is an important distinction between quality of crop and quantity, the attainment of the optimum in either direction being not always compatible one with the other. Frequently if not generally these ends are antagonistic, and it is a question of nice judgment so to adjust the several factors determining crop production as to obtain the best compromise between quantity and quality. For such a judgment, and such an adjustment, there is requisite a knowledge of the several factors, their several functions and their relations to one another. Crop production is the resultant of many factors. It depends upon the biological characteristics of the plant, upon the viability and germinating power of the seed, the species and varietal differences. It depends upon climate especially, the amount and distribution of rainfall and of sunlight, and upon temperature variations. It depends upon the soil, including the composition and character of the mineral components and of the organic substances, including the yet mysterious complex, humus. It depends upon the physical properties of the soil, its textural characteristics, its absorptive powers and water movements; upon the biological properties of the soil, including bacteria, molds, enzymes. With these natural factors may be included others of which at present no opinion can be ventured other than the possibility of their existence. To these in the case of cultivated crops, must be added three artificial factors which comprise nearly all that man has yet devised for the control of soil and crop, namely, tillage methods, rotations, and fertilizers. The use of wind brakes, shades, glass houses, etherization, spraying, etc., are all very special practices for special cases, and need not be considered in a general discussion, as they have no wide application to field crops.

Consideration of the factors determining crop production and the experimental investigations of them, brings a realization that the resultant of all these variables is complex. Not only are the factors numerous but they are interdependent, and no one of them can be changed without producing corresponding changes in all the others. These are points of great importance, for up to the very recent past it has been assumed that crop production is a simple matter, dependent primarily upon the amount of plant food available, although it was recognized that the weather sometimes interfered and that some tillage was necessary to the production of any crop at all.

Let us confine ourselves for the present to a consideration of the soil factors. The soil is the resting place for the products of practically all the activities taking place on the face of the earth. Agriculturally we may confine the term soil to that portion of the solid crust of the earth which is or can be adapted to the growth of crop plants, and in it are to be found results of these various activities, natural and artificial. The soil contains a vast array of mineral particles. It is true that sometimes certain minerals or groups of minerals will predominate and give convincing evidence of the rock origin of the soil. Sometimes, however, the soil shows no obvious relation to any particular rock. But investigations to which attention only

can be called at this time, have made clear that practically every soil contains some at least of every *kind* of rock forming mineral. To these are added the products of organized life and the degradation and decomposition products resulting from them. Mineralogical investigations showing the large numbers and variety of minerals present in every soil are equalled in importance by some recent chemical investigations which show an amazing variety of elements. In each of a series of soils from different sections of the United States, east of the Mississippi, there has been found in detectable and generally in estimable quantities nearly every known element. And in the organic residues of ordinary soils which have been under cultivation, there have now been isolated and identified some twenty definite chemical individuals, of at least eight different types.

Water and winds are constantly transporting soil material from place to place, so that in all cases the soil is far more heterogeneous than any rock. Aside from the heterogeneity of soils, the results of these activities of water and winds are easily recognized. Throughout the humid areas of the world it is a general rule that the surface soil is lighter in texture than the subsoil, though the former is derived from the latter, the smaller particles being more easily removable. In arid regions this rule will not apply, for special conditions determine soil formation in each and every area. Within any given area of the soil itself we recognize that the particles must be moving continually. The sinking of heavy objects into the soil is an evidence of this. We know that earth worms, burrowing animals and like transporting agencies are of great importance, but more than these is the importance of the alternate wetting and drying of the soils incident to weather changes, which wetting and drying is accompanied by expansions and shrinkages which do not exactly balance one another and which must in consequence be accompanied by movements of the individual particles of the soil, and by a considerable mixing and transporting of these particles among one another. From the very nature of the case we know that living organisms within the soil must be moving, and all the biological factors are continually in process of change.

The water falling upon the earth makes possible the use of the material as a medium for plant growth by bringing in solution to the absorptive tissues of the roots, the mineral elements which we all now recognize as essential to the growth of plant and animal. In falling as rain, a portion of this water fails to enter the earth by remaining in the air as vapor. Another portion runs off from the surface, while the remainder enters the soil and percolates through it, mainly as the result of gravitational forces and through the larger soil openings. Some of this water goes into the soil, seeps through and appears at the surface in the form of springs and wells and passes off into the drainage of the area. This water, dependent upon the character of the soil, the length of its passage and other obvious factors, dissolves from the soil some of the mineral matter, and so we find all our creeks and rivers diluted soil solutions of varying composition and concentration. As the surface of the soil dries there is developed there a capillary drag or pull, and some of the water which has entered the soil reascends to the surface, generally more slowly than it penetrated into it, passing in this case over the surface of the soil grains as films, being long in

contact with them, so that there is continually being brought to the surface of our soils a solution containing the mineral elements, including those necessary to plant growth. So far as investigation can determine the matter at present, it appears that the concentration of this solution does not vary very much in composition with respect to those mineral constituents which are recognized as of importance to plant growth, at least within a given area or in areas under similar climatic conditions, and the concentration of the solution, except in special cases, is much higher than that of the seepage water, being on the average in the United States probably ten times as high.

Calculations based on observations of the rainfall and runoff of our principal areas, as well as some direct experimentation, show that under normal conditions such as those obtaining in the humid areas of the United States, upwards of two-thirds of the rainfall enters the soil, penetrates to the subsoil, and returns to the surface, carrying with it dissolved material which is available for plants. A consideration of this line of inquiry leads to the conviction that practically all the mineral plant food utilized by growing crops is being brought to them from the subsoil where the roots do not actually penetrate. There is much evidence in favor of this view, though time will not permit me to lay it before you today. But it is clear that we must recognize not only the interdependence of soil factors as well as other factors in crop production, but we must recognize furthermore that every factor in the soil affecting crop production is continually changing, and that the problem is essentially a dynamic one, not susceptible to the application of static considerations, which have so long been popular and in some quarters are still so. The analogy of the soil to a bank from which deposits of plant food are being drawn is essentially false. Rather is the soil like to a complicated machine with many parts, each running according to its own specific purpose, but the whole to the general purpose of turning out a definite finished product; and this product in quality and in quantity is determined by the way each separate operation is performed, as well as by the character of raw material furnished. Like such a machine the soil if not used or if misused, "rusts," but properly used it increases in efficiency. Analogies are, however, very dangerous as arguments, and I would not have you fail to recognize that in some essential features the soil no more resembles such a mechanical device than it does a bank.

With these soil factors admitted, another conviction comes to mind. A simple substance has but relatively few characteristics. One amoeba is like another, one drop of water is not essentially different from another. As complexity increases, so does differentiation, and as we pass to the highest complex of which we have any knowledge, the civilized human being, the differences between one man and another are quite as prominent as the similarities. Two engines built from the same shops, from the same patterns and in the hands of the same engineer differ in performance as a rule. The soil is extremely complex, consequently no two soils are alike, and the more they are studied the more it becomes apparent that the differences not only between soil types but between different fields of the same soil are fully as important as are the similarities. No two fields can be expected to have the same crop producing power or the same adaptability to crops or rotations of crops, or the same

responsiveness to a given tillage method or fertilizer treatment. In other words, soils are highly individuated, a fact not generally recognized, but of the first importance to an intelligent and rational management.

Let us turn now to a consideration of the instruments or methods of soil management. As stated before, these may be classified under three general heads, tillage, crop rotations, and fertilizers. The essential fundamental facts which it is important to bear in mind here is that no one of these methods can be expected to take the place of the others, although they do all affect the same natural factors and consequently are thus mutually interdependent. Tillage obviously affects the physical properties of the soil, but it affects also the chemistry of the soil, for the altered movements of water, of carbon dioxide content of air, and possibly other relations in the soil affect profoundly the inorganic and organic relations. No less profoundly are the bacterial flora and other biological features affected. But fertilizers, as recent investigations are making obvious, produce as profound changes in the physical properties of a soil as do tillage operations, and that they affect the chemistry and biology of the soil no one can question. Nevertheless in their net results we must consider tillage and fertilizers as differing not only in intensity or amount, but essentially in kind. Two great errors with their attendant lessons are before the American public at the present time. In the South Atlantic States tillage has been, speaking generally, poor and unsatisfactory, rotations uncommon, and the dependence is upon fertilizers under the mistaken idea that plant foods alone are what the soils need. In the trans-Mississippi areas generally rotations are again neglected, fertilizers are seldom used because of the supposed superabundance of plant foods or "fertility," and the dependence is alone or almost entirely on tillage.

Time will not permit of any great amplifications of these illustrations, but abundant evidence is coming to hand that both procedures are at fault. The introduction of diversified methods of farming and better tillage in the South has established beyond question that the soils of that region have a value for crop production immeasurably higher than the popular notion. The increasing demands for the lands of the western States has directed attention to their yields. There is a popular impression that these yields are falling off—a doubtful opinion in view of such official records as are available, but it is certain that they must increase to justify the continuance of their relatively high money value, and if they are to meet the growing demands of an increasing population. The lessons which these considerations teach are sufficiently clear. Modifications of tillage methods, introduction of new fertilizer materials, adaptation of rotations to special soil peculiarities, climatic environment or market conditions will undoubtedly be worked out for each locality, but essentially the principles are the same.

It is an interesting fact worthy of the most serious consideration of both the scientific investigator and the practical layman that we have no definite idea as to the limit of productivity of which soils are capable. Under greenhouse and laboratory conditions yields can be obtained enormously higher than are actually gotten in the field. This is contrary to the general rule in industrial operations. It is well established that the factory practice is more efficient than the laboratory. For example,

the operation of crystallizing cane sugar, practically pure, in the mill is a commonplace of the industry, but can not be accomplished on a laboratory scale. I have recently been assured by one of the most skillful metallurgists in this country that certain methods which he had studied for years in the laboratory only to find that they "would not work" although theoretically sound, were found to be very easy of accomplishment and remarkably efficient when he finally had the courage to try them in actual smelter runs. These facts indicate that in soil management, actual performance is yet very far behind what we have a right to expect. But more than that, the yields obtained in artificial cultures, so far from showing what the maximum possibilities are, should rather be regarded as indicating the inferior limit allowable in actual practice. This view may seem revolutionary to some, and it would be, if we are to look forward to an indefinite continuance of farming by present methods. But actual examples of sustained yields of high quantity in such special crops as truck, tobacco, etc., show that the possibilities have not yet been realized and that with the development of the future, present results will look woefully inadequate. It is but a few generations since the physician was regarded as a sort of lower servant who practiced with approbation crudities that today would land him in the madhouse; today he performs as ordinary incidents of the day's routine operations that were not impossible but undreamed of a half century ago, and his position in the community is not surpassed in the homage and respect it commands. The profession of engineering of today has developed from equally humble origin and other examples will occur to every one. It is not so long since the farmer was a serf, but there are many reasons to believe that soil management is developing in a similar way to medicine, law, engineering, etc., as witnessed by the existence of such institutions as the one in whose halls we are now met, and by the fact that it commands the gathering in conclave of trained investigators in such diverse inquiries as have been brought before us today. The view is not revolutionary, but will, I am sure, appeal to you as entirely logical, and that if the technical investigators do well their part, the farmer of the not distant future will not be behind the smelter superintendent or the up-to-date manager of the factory.

Soil management is for the production of the crop and the crop is made up of plants. The modern crop plant is already a highly artificialized entity. It is not reasonable to expect the co-ed graduate of Michigan's higher seats of learning, however satisfactory and beyond criticisms she may be in her native environment, to make a satisfactory wife to the roving Hottentot or the nomadic Esquimau. Just as reasonable is it to expect a highly bred strain of wheat to fare well on a soil and under management that would discourage a jimson weed. It is not a question of food; your Esquimau eats more than your college athiete, and gets it when his civilized compeer with all his modern equipment would starve, yet the Esquimau is inferior in production either of physical or mental output. Our soil management must be developed with this thought constantly in mind that the organisms for whose production the management is practiced is highly artificialized and cannot maintain itself successfully without continual supervision and aid. It is not surprising therefore that the soil must be artificialized to some extent for the best production of the artificialized plants. The thoroughly tilled

and freshly fertilized field is better suited to crop production than a virgin prairie, but also more sensitive to mistakes in management or judgment. Far too often is the soil blamed for the shortcomings or errors of the farmer. By slight changes of condition in the laboratories we can induce a seedling plant to grow long or short roots as compared with the tops; but does any one yet make use of this knowledge in growing a field of wheat? Mineral nutrients are essential to metabolism in all organisms, but is it not foolish to pin our faith on this alone, when for instance it has been shown that the ragweed following a wheat crop takes out of the soil more of the mineral nutrients than does the wheat crop. Rather is it not more reasonable to infer that the inability to produce a satisfactory repetition of the wheat crop is due to the fact that so artificialized a plant as the wheat, in which habits have been bred into characteristics, can thrive only under a special combination of soil, climate and seasonal factors which can not be realized in the soil from which the crop has just been removed.

We are led here to consider another important generalization which has not received the consideration it should. It is a characteristic of all activities, physical, chemical or biological, that as the activity proceeds in any definite direction, products of the activities accumulate and slow up the action, ultimately stopping it if the products are not removed. This generality holds for waste products or so-called by-products as well as for the main ones. The factory cannot continue unless by-products are removed. Manure must sometime be removed from the barnyard. Every housewife knows that the kitchen cannot be managed without removal of the garbage. In chemistry we have the well known law of mass action which in different forms has its application in physics and biology. The bacteria or the yeast cannot continue to live and thrive when the medium in which it exists reaches a certain concentration with respect to its reaction products, a familiar example being the fermentation of sugar to alcohol. But some other ferment can, however, live and thrive in the medium, as the butyric acid ferment. Rats are said to be able to live in an environment which man or some other higher animal has fouled beyond the point of habitability.

So with our crop plants. Because of their higher artificiality they are the more prone to unfit their environment for continued production, unless the environment be artificially assisted by suitable management, and to this end we must investigate the causes, whether toxic organic substances, disturbed bacterial associations, or whatever they may prove to be in any particular case. The principle to which the president of the American Chemical Society called attention recently as a universal law, finds ready application here. The ragweed requiring as much "food" and water as the wheat will grow in the soil which cannot be replanted to the latter, but (in certain regions which have been under my own observation at least) the ragweed itself gives place the following spring to blue grass.

What then is the theory of soil management? In the sense of a simple, formal statement, there is no theory. At the best such statements can be but a part of the whole truth which is the basis of soil management. It is never true that the crop growth is or would be determined by a minimum content of any one mineral element or by a maximum content of some organic substance, or by a given ratio of protozoa to bacteria

or ratio of water content to air space. Any one of these may, in a particular case, be a factor of even predominating influence, but always the crop is determined by a large number of factors, and it is not rational to describe any one of these various contributing factors in crop production as a theory of fertility or a theory of soil management.

The increase of knowledge concerning the chemical processes taking place in soils, the function of water as a great reactive agent in preparing the mineral constituents for the easy assimilation of plants, the translocation of such materials from subsoil to surface soil, the part that other mineral constituents than those recognized as plant foods may and probably do play in affecting quantity and quality of product, the chemical and physical effects of organic substances which are now being separated and recognized by definite scientific criteria, the biological activities, the various types of bacteria or their antagonists, the protozoa, all this information in each and every case comes back practically to the question of soil management. How they are controlled by tillage, by rotation, by fertilizers; how a just balance between these factors is to be sought for the production of a crop of given quality or given mass or volume. Such an adjustment must always be a matter of judgment. Therefore soil management is an art, dependent upon investigations of a large group of sciences, which we can call for convenience, *agricultural science.*

In the practice of this art the labors will be much lightened if the expert has an intelligent clientele. No effort should be spared to bring the modern concept of the soil and its relation to crop production to every farmer in the community. It will be found more interesting and more reasonable than the stereotyped views which have preceded it and so long maintained their sway. And with an assimilation of these ideas will come a mutual understanding between the farmer and the expert. With a recognition of the fact that the soil is an individual and must be treated as such will come an effort on the part of the farmer to adjust his management to it, and enable him to put before the expert a clearer picture and to formulate a cleaner question when difficulties are encountered. Nothing is more trying to the soil investigator than to be sent a sample of soil and to be asked to analyze it and tell what fertilizer it needs and what crops will grow on it. But yet the question is a fair one under past conditions and the expert has no one to blame but himself for the fact that the layman does not know that no stereotyped method of examination, physical, chemical, or biological can possibly tell what a dynamic system will do under a specific but dynamic environment.

Quite recently there has been a great public awakening in this country, a prominent feature of which is a greater appreciation of the importance of the nation's soils. The time is ripe for the minds of the people are in a receptive mood for the newer knowledge which such gatherings as this are making available. Surely the farmer will take a keener and more intelligent interest in his soil when you show him that instead of being a dead, inert mass of rock and plant débris, it is scarcely less active than his stock; that changes are going on in it all the time, changes which are as susceptible to control as the feeding and working of his stock. That each field is an individual which he must continually study, coax, repress or force as he would his growing herd. The true soil management absolutely precludes monotony, for never twice does the same field,

even with the same crop, present just the same problems, and no stereotyped practice can bring the best results any more than a stereotyped "analysis" will enable you to advise him.

The State of Michigan is to be congratulated in that the Academy of Science recognizes the importance and the character of soil investigations by formulating the comprehensive program of today. The State is to be congratulated that the State Agricultural College and Experiment Station have inaugurated the comprehensive and coordinated investigations which have made possible this program. For alone, neither the chemist, the physicist or mineralogist, nor the biologist can longer hope to advance in soil work. Each must have the continued assistance of the others. No longer can the Michigan farmer continue with success the methods of his father or grandfather. He must develop a judgment that will enable him to handle each particular field according to its own individual merits for definite crops or rotations. To this end he can now command invaluable assistance from the soil surveys; from the office of the experiment stations; and from the professors in the State Agricultural College. Above all, from his own observations and deductions can he get direction for the future. But to get intelligent counsel from reading, observation, or expert, the farmer must know the nature of his problem and the character of the principal processes taking place therein.

To sum up, the principal points that I would like to emphasize are: That soils are complex, but that they are susceptible to management and the development of high efficiency; that the methods for doing this are fairly well known; that in its major outlines the theoretical basis of soil management is fairly simple, and that its practice is rapidly becoming a highly developed art which needs for its best application a comprehensive coordination of the labors of the physicist, chemist, biologist, and other investigators, and a clearer understanding between the layman and the expert as to how they may be mutually helpful.

Washington, D. C., April, 1911.

RELATION OF THE RURAL HIGHWAYS TO THE CONSERVATION OF MICHIGAN'S RESOURCES.

FRANK F. ROGERS.

It has been said: "That nation can longest survive in the struggle for existance and supremacy which can most nearly supply all the needs of its people without going into foreign markets to purchase them." That is, the nation that from its soil, its mines and its workshops can produce all that is really necessary for the sustenance of its people can most successfully resist attacks from without, whether in the form of military or commercial warfare. It has also been said that the United States more fully than any other nation possesses these potential resources.

Now, if we will look over our own state, I am sure that we shall all agree, that of all the states in the Union, Michigan is, or could be, the most nearly self-supporting. Its wide range of agricultural products covers most of the fruits, grains and vegetables, including the sugar beet, which practically supplies the sugar consumed by us, or its equivalent in weight. The forest products of Michigan once seemed inexhaustable, but unfortunately they were not conserved. Even now, we have enough cut-over land and young growth, if the forest fires could be kept away from it, to supply our timber needs indefinitely. We have the most important minerals, such as coal, iron, copper, salt, gypsum, marl, limestone, etc. These products have not only made manufacturing possible, but very profitable. Finally, since a few large corporations have discovered that we have thousands of horse-power running to waste in many of our rivers, we are just beginning to wake up and plan what we can do to conserve the remnant of this heritage that is left us.

With one exception, cotton and its products, it looks as if Michigan, if compelled to, could live within itself and produce all that is really necessary for the well being and comfort of its people. While the writer is not advocating any such foolish policy, it is good for us at times to look about us and admire, not only the beauties suggested by the inscription on our seal, but the material worth of the many gifts that nature has bestowed upon us.

Michigan is credited with a land area of 57,480 squares miles, (Ninth Annual Report of Michigan Academy of Science), which is equivalent to 36,787,200 acres. In 1900 it had 203,261 farms aggregating 17,561,698 acres, which is nearly 48% of the area of the State. Of this farm land 11,799,250 acres, or 67.2%, were reported as cleared and more or less under cultivation. These farms, equipped with machinery and stock, represented a total value of $690,355,734, which sum is nearly 40% of the present assessed valuation of the State.

From reports of the Secretary of State, I learn that these farms produced in 1910 15 million bushels of wheat, 54⅓ million bushels of corn,

46½ million bushels of oats, 1¾ million bushels of barley, 6 million bushels of rye, ¾ million bushels of buckwheat, 25½ million bushels of potatoes, 6 million bushels of beans, ¾ million bushels of peas, 6½ million bushels of apples and one million bushels of peaches besides numerous small fruits. These, added to 900,000* tons of sugar beets and 2¾ million tons of hay, make a grand total of 8 million tons of farm products, a large percentage of which must be hauled over the country highways before reaching the local markets. In addition to this a large tonnage from the forests and mines also passes over the country roads, so that it is doubtless within the truth to say that fully 8 million tons of freight are annually hauled, a greater or less distance, over the country highways of this state, to say nothing of their use for other purposes.

Lord Bacon said: "There be three things which make a nation great and prosperous, a fertile soil, busy workshops and easy conveyance for man and goods from place to place." We have taken a brief inventory of the products of the soil and now begin to realize something of the magnitude of the transportation problem of our state from the farmer's standpoint. As most of the goods from the mine and factory are usually delivered to the railroads direct, with little or no wagon haul, that phase of the problem may be overlooked in this discussion, except as above noted.

The waste in the expenditure of the present large sum annually going into the up-keep of our highways due to poor and antiquated methods together with misdirected work, added to the waste caused by the transportation of our products over roads much poorer than they should be, present a field for the conservation of a part of our resources large enough to demand serious consideration from the best citizens of our commonwealth.

The transportation facilities of Michigan at present are: 1620 miles of coast line on the Great Lakes, 8,592 miles of steam railways, exclusive of second tracks, sidings and proprietary lines. (1909 Report of Michigan Railroad Commission), 992 miles of interurban electric roads and approximately 70,000 miles of public wagon roads outside of the corporate limits of cities and villages. This equals 1.23 miles of highway for each square mile of area and one mile of highway for each 36 persons, according to the 1900 census, the figures for 1910 not being available.

The cost of transporting freight on the Great Lakes has been reduced on long hauls to about one mill per ton mile, on the steam roads to about 5 mills per ton mile, while on the average rural highway, with animal power, it still ranges between 20 cts. and 25 cts. per ton mile. On the best English highways, with power tractors, the cost has been reduced to about 5 cts. per ton mile.

The average length of haul for farm products in the United States was determined by the Department of Agriculture as 12.1 miles. Professor I. O. Baker takes exception to this and determines it for the state of Illinois at 4.8 miles. Michigan is not so thickly covered with railways as is Illinois, and if we assume the average haul for this state at 5 miles, we shall certainly be giving our factor of ignorance the

* A later report from the secretary of Michigan Sugar Company shows that 1,079,400 tons of beets were grown in Michigan in 1910.

benefit of the doubt. Now, the difference between the cost of moving this 8 million tons of freight over the country highways in their present condition an average distance of 5 miles and the cost of moving it over the kind of roads we should have, represents a part of the money we hope to conserve when, even our main traveled highways become good.

From the figures above given it is apparent that this cost could be cut, at least in the middle. A saving of 10 cts. per ton mile for this average haul of 5 miles on 8 million tons of farm products would mean a saving of $4,000,000 annually to the people of Michigan. Possibly this is visionary, but it is hard to show flaws in the reasoning.

However that may be I seldom indulge in such arguments, for I prefer to deal more specifically with what might be accomplished with the funds now available for road purposes in the state.

The following table shows the township and county road taxes levied and collected in Michigan since 1901:

YEAR.	TOWNSHIP TAX.	COUNTY TAX.	TOTAL TAX.
1901	$2,253,039 45	$166,441 76	$2,419,481 21
1902	2,462,816 29	179,826 45	2,642,642 74
1903	2,600,727 04	239,031 58	2,839,758 62
1904	2,937,219 69	266,555 79	3,203,775 48
1905	2,976,077 47	285,963 80	3,262,041 27
1906	2,985,989 17	420,321 10	3,406,310 27
1907	3,091,647 59	421,307 07	3,512,954 66
1908	2,916,817 01	529,452 45	3,446,269 46
1909	3,014,344 94	741,868 05	3,756,212 99
1910	3,264,049 30	859,157 50	4,123,206 80
Total	$28,500,727 95	$4,109,925 55	$32,610,653 50

The yearly average is 1-10 of the above totals.

These figures show an average highway tax of $3,261,065.35 for these 10 years. The increase has been gradual, there being only two years when the tax was not higher than that of the preceding year. The total increase in 10 years is more than 70%.

In 1907 statute labor for highway maintenance was abolished and all highway taxes in the state are now paid in cash. Even this change, reduced the tax of 1908 less than 6% over the tax of 1907.

But Michigan should not be satisfied with her progress in road betterment. I believe that it is easily possible to gravel or macadamize all the leading highways in the state within the next two decades, with but slight increase in the present rate of taxation, were all the money used to the best advantage. The problem is not so much one of raising more taxes, as how best to use the money already at our disposal.

Not more than one fifth of our 70,000 can be classed as main traveled roads. As heretofore shown we have less than 10,000 miles of railroads, including the interurban lines, which reach all of the cities and nearly all of the villages in the state. If to these we add 4,000 miles of highways, making a total of 14,000 miles, there can be no question

but every hamlet would be reached and every important artery of travel included in the system.

Michigan's state reward road law became operative in 1905. It provides for paying a bounty ranging from $250 to $1,000 a mile for roads completed in the manner prescribed by the state specifications. The reward on gravel roads is $500, and on macadam roads $1,000 a mile.

In the five years ending July 1st, 1910, there had been completed 545.5 miles of roads on which state rewards were paid. 297 miles of this were gravel, 234 miles macadam, and 14.5 miles were the various other kinds of roads on which state rewards can be paid.

The money raised by state taxation to pay these rewards is not included in the highway taxes above given.

Taking the 545.5 miles of road completed previous to July 1st, 1910, the date of the Department's last biennial report as a basis, we find the average cost of improved roads of all kinds to be $3,180 a mile. The average state reward paid per mile was $719; hence after deducting the state bounty, the average net cost to the community building the road was $2,461 a mile. Now, taking the $4,123,206.80 highway tax of 1910, for example, what could we have accomplished?

Last year the commissioner's reports show that $631,505, an average of about $9 per mile, were expended on bridges and culverts, while $859,157.50 of the above amount were expended in the construction of county roads. Deducting these two sums from the total highway tax above given we have left $2,632,544.30 which went into the up-keep of our 70,000 miles of highways and such permanent work as may have been done by the several townships. It is an average of about $37.60 a mile.

Where the King drag, or other kinds of drag that accomplish the same purpose, have been systematically used, it has been proved that well graded and drained earth roads on clay or loamy soils can be kept in good condition, at all seasons of the year when it is possible for such roads to be good, at a total annual cost of much less than $10 a mile.

Mr. K. I. Sawyer, county road engineer of Menominee County, reports that a thorough system of dragging followed up the entire season reduced the cost of up-keep on the earth roads under county supervision from $28.17 a mile in 1909 to $8.65 a mile in 1910, at the same time keeping the surface in as good or better condition than formerly. This is a net saving of $19.52 a mile, or more than 69%.

About 40% of the roads of Michigan are so sandy that this kind of treatment is of very little use. In fact very little money should be expended on such roads, except to maintain a fairly even surface and conserve the moisture until such time as they can be given a hard surface. But suppose we should expend $10 on every mile of road in the state each year, it would only take $700,000 and would leave $1,932,544.30 that could and should be used for permanent work. At a net average cost of $2,461 a mile to the communities building, (and that has been the average for the past 5 years) this sum would construct 785 miles of improved road in the state each year, and would complete the entire 14,000 miles of main highways in the state in 18 years.

To do this the state would have to raise sufficient funds to pay the bounties and necessary supervision, which would mean a state appropriation of not less than $600,000 annually. Last year 276 miles of road were built on which state reward was paid, an increase of 26% over the previous year. It now looks as though the state bonuses that will be paid during the present fiscal year would show an increase of more than 40% over those of the previous year. If this rate of increase can be maintained, three years from now we may hope to be building at the rate of 800 miles a year and thus make it possible to see our trunk line highways completed within the next 20 years, but not without a cost far in excess of the figures given.

Lansing, Mich., April, 1911.

PROGRESS OF THE GEOLOGICAL AND BIOLOGICAL SURVEY OF MICHIGAN.

R. C. ALLEN, DIRECTOR, AND A. G. RUTHVEN, CHIEF FIELD NATURALIST.

Geology and Topography by R. C. Allen.

Members and friends of the Michigan Academy of Science:

In accordance with the invitation of the Academy so courteously extended to us last year I have the pleasure to transmit to you a report of the progress of the Michigan Geological and Biological Survey. The work of the department of Geological and Biological Survey is conducted under three divisions, each of which is provided with a separate appropriation. These divisions are:

1. The division of Geology established by the law of 1869, providing for a continuing appropriation of $8,000 annually.

2. The division of Topography which is conducted under special appropriation from the legislature, the appropriation for the fiscal years 1909-1910 and 1910-1911 being $2,000 per annum.

3. The division of Biology established by law of 1905 which is also conducted under special appropriation from the legislature, the appropriation for the fiscal years 1909-1910 and 1910-1911 being $1,000 per annum.

The law of 1869 as amended provides that a survey shall be conducted under an ex-officio board, which shall be composed of the Governor, Superintendent of Public Instruction, and the President of the State Board of Education, who shall constitute a Board of Geological Survey. This Board is directed to "appoint and commission a suitable person, possessed of the requisite knowledge of the science of geology, who shall be Director of the Geological Survey hereby instituted." The Director has, by custom, since the passage of this law, been called the State Geologist. The act of 1905 establishing a biological survey reads in part, "that the Board of Geological Survey is hereby authorized and required to make, under the direction of the State Geologist appointed by them, a thorough biological survey of the state." It appears then that the State Geologist referred to in the law of 1905 and the Director of the Geological Survey, the position established by law of 1869, are one and the same person, so we have, therefore, in this state as constituted at present, a Geological and Biological Survey under the direction of a Board of Geological Survey and prosecuted under supervision of a Director, whose appointment and commission is provided for in the law of 1869 as amended and who is referred to in the law of 1905, establishing a biological survey, as a State Geologist.

At a meeting of the Board of Scientific Advisers in April, 1910, it was recommended, and approved by the Director and the Board of Geological Survey, that the organization be called the Michigan Geological and Biological Survey.

The division of Biology is conducted under the direct charge of a Chief

Field Naturalist, who is appointed by the Director, with the approval of the Board of Geological Survey. Dr. Ruthven reported to you at the last meeting the progress of the biological survey and will report to you at this meeting the progress of the biological survey during the past year.

The report upon the progress of the geological and topographic work which follow covers the period from my appointment, September 1, 1909, to date.

GEOLOGY.

Active field work has been prosecuted in the Northern Peninsula in both the copper bearing and iron bearing districts, and in parts of the Southern Peninsula.

Northern Peninsula.

Copper Country: Report on the Geology of the Keweenawan or Copper Bearing Rocks.

My predecessor, Dr. A. C. Lane, had, during his long period of services as State Geologist, become especially conversant with the geology of the Keweenawan or copper bearing rocks and at the time his resignation became effective had partially completed a monograph on the Keweenawan Series of Michigan designed to be an exhaustive treatise embodying all information of scientific and economic importance on the subjects treated. Dr. Lane was therefore requested to complete his work as soon as practicable and money was appropriated for the purpose from our funds. The Survey has co-operated with Dr. Lane in bringing this work to successful completion. Mr. Karl S. Meuche was employed as assistant to Dr. Lane. The manuscript of this report is now complete and ready for publication.

Iron Region: Report on the Geology of the Iron River District.

Prior to his appointment as State Geologist the writer had been engaged by the Board of Geological Survey to make a survey and report upon the geology of the Iron River district. Field work was prosecuted during the summer of 1909 and also during a part of the summer of 1910, which was followed by a report, published and distributed in February, 1911.

Geologic Mapping West of the Iron River District.

During the summer of 1910 a party of from 4 to 7 men were engaged in geologic mapping of 11 townships, viz.: T. 45 N., R. 35 W., Tps. 42, 43, 44 and 45, R. 36 W., Tps. 42, 43, 44 and 45, R. 37 W., and Tps. 43 and 44, R. 38 W., lying west of the Iron River district. Blue prints of the field plats may be obtained at cost on application. The completion of the work on the Iron River district and the mapping of these townships forms a very good beginning on the general plan of mapping as rapidly as possible the unmapped Huronian areas of the Northern Peninsula. A reward of careful magnetic work, which was carried on simultaneously with the geologic mapping, was reaped in picking up a magnetic belt in Section 16, T. 43 N., R. 37 W., and carrying it thence westward over a deeply drift-covered area where there are no rock exposures, to the state boundary in Section 16, T. 43 N., R. 38 W., a distance of about 6 miles. This magnetic belt is doubtless underlain by iron bearing rocks which in the future will be explored by drilling, with the probable result that bodies of iron ore will be discovered and exploited.

A map of the Surface formations and soils of the northern peninsula.

During the past 5 years the survey has been co-operating with the U. S. Geological Survey in the mapping and study of the glacial or surface formations of the Northern Peninsula. The field work was completed under charge of Prof. Frank Leverett during the summer of 1910 and a map on a scale of six miles to the inch is now finished and ready for publication. It will show in appropriate colors and symbols the distribution of the various classes of soils and the features of glacial geology, etc., on an excellent black base. It is planned to issue an edition of 3,000 of this map and a new edition of 3,000 of a similar map of the Southern Peninsula, which was published in the annual report for 1907. These maps will be accompanied by a descriptive text by Prof. Leverett, written in simple style in order that it may be fully comprehended by the average Michigan farmer. We have now on file many advance applications for this work. It will aid very materially in the agricultural development of the unpopulated areas of the Northern Peninsula and the northern half of the Southern Peninsula. The publication of these maps and descriptive text is timely, in view of the awakened interest in agricultural development, especially in many parts of the Northern Peninsula.

Southern Peninsula.

Report on the Monroe Formation of Southern Michigan and Adjoining Regions.

The work of Professors Grabau and Sherzer which has been in progress for several years has been completed and issued as Publication 2, Geological Series 1. This is a monographic report of about 250 pages, not including about 100 pages of plates and descriptions of fauna and flora. The execution of this work does credit to the ability of the authors and the painstaking care with which the work has been done. The high praise accorded it by the lay and scientific public is a source of much gratification to the Survey.

Report on the Geology of Arenac County.

The text of a report on Arenac county, by Prof. W. M. Gregory, has been completed and is ready for publication. This report is characterized by the same thoroughness of treatment which marks the volumes already published on Monroe, Huron, Sanilac, Bay and Tuscola counties.

Report on the Geology of Wayne County.

A report on the geology of Wayne county is in the course of preparation by Prof. W. H. Sherzer. This work should be ready for the press before July, 1911. We have had many requests for this work in advance of its publication. It will treat in a manner easily comprehended by the reader of average intelligence of the geology, physiography, soils and mineral products of the most populous county of the state.

Report on the Salt Industry.

Field work in the preparation of a report on the salt industry of the state was begun by Mr. C. W. Cook in June, 1910, and continued

throughout the summer. Work in preparation of this report is being pushed as rapidly as possible and it is hoped that it will be finished before the end of 1911.

A General Geological Map of the State.

It is planned to issue a general geological map of the state on the black base, scale six miles to the inch, used for the soil map above mentioned, the same to be accompanied by a short descriptive text setting forth in a manner easily comprehended by the non-technical reader the salient features of the general geology, including brief descriptions of the rock formations in the order in which they occur in the geological column, with special reference to features of economic importance. This text is designed only to render the interpretation of the map intelligible to the average reader. There have been received a large number of requests for this map from the schools and educational institutions of the state, citizens, and from many sources outside the state.

Report on Earthquakes in Michigan and the Tilting of the Basins of the Great Lakes.

This report which is ready for press, has been prepared by Prof. Wm. H. Hobbs. It will have special value to school and college libraries and teachers of physiography and geology. The text is beautifully illustrated with numerous pen drawings especially prepared for this report.

Correspondence.

The Survey receives by mail many requests for information on subjects of wide range. These receive the personal attention of the Director and constitute no small draft on his time when not on duty in the field. Some idea of the number and character of the inquiries received may be gained by a glance at the tabulation below, which includes only such inquiries as have been answered by letters. Requests for publications, i. e., reports, maps, etc., are not included in this classification, nor the many requests delivered in person in the office. Some requests are for information on two or more subjects which explains the higher total under classification by subjects. Neither list includes a large number of inquiries which have been received by the Chief Field Naturalist in charge of the biological division.

By calculation it has been ascertained that the number of requests for information thus far in this year exceed those of last year by about

Classification of Inquiries by Localities from Which They Were Received.

July 1, 1909, to December 14, 1910 (inc).

County.	No. of inquiries.	County.	No. of inquiries.
Alcona	1	Lapeer	1
Allegan	1	Lenawee	3
Alpena	2	Luce	3
Antrim	4	Mackinac	1
Baraga	2	Macomb	3
Barry	1	Manistee	1
Bay	6	Marquette	11
Berrien	3	Mason	8
Branch	1	Mecosta	4
Calhoun	7	Menominee	3
Cass	2	Missaukee	4
Charlevoix	10	Monroe	4
Cheboygan	10	Montmorency	2
Chippewa	6	Muskegon	1
Clare	1	Oakland	3
Clinton	1	Oceana	2
Delta	9	Ontonagon	1
Dickinson	6	Osceola	2
Eaton	2	Oscoda	1
Emmet	3	Ottawa	1
Genesee	8	Presque Isle	11
Gogebic	2	Roscommon	2
Grand Traverse	6	Saginaw	5
Gratiot	6	Sanilac	2
Houghton	14	Schoolcraft	1
Huron	3	Shiawassee	2
Ingham	7	St. Clair	3
Ionia	2	St. Joseph	2
Iosco	2	Tuscola	9
Iron	20	Van Buren	1
Isabella	11	Washtenaw	19
Jackson	4	Wayne	81
Kalamazoo	12	Wexford	1
Kent	24	Outside the State	311
Keweenaw	2	Foreign countries	21
Lake	1		
Total			732

Classification of Inquiries by Subjects.

Subject.	No. of inquiries.	Subject.	No. of inquiries.
Altitudes	1	Maps	174
Biology	52	Marl	8
Bromine	1	Minerals	30
Cement	11	Miscellaneous	100
Clay	4	Oil	15
Coal	26	Peat	51
Copper	12	Salt	18
Drainage	3	Sand	9
Fossils	4	Sandstone	1
Gas	10	Shale	1
Geology, general	110	Soda	1
Gold	4	Soil	26
Granite	2	Stone	5
Gravel	2	Swamps	7
Gypsum	18	Topography	7
Iron	18	Water	17
Lime	3	Wells	7
Limestone	8	Zoological	1
Total			769

Identification of Specimens.

A large number of mineral specimens have been received from prospectors and others with requests for identification and other information concerning them. In many cases the specimens are accompanied by requests for chemical analyses. The Survey does not maintain an analytical laboratory, and even if it did it would probably not be wise to compete with professional analysts in making analyses for private individuals. However, in a great majority of instances the specimens have been fully identified, where necessary by qualitative dry and wet tests, and the information furnished free of charge, thus saving the cost of a chemical analysis.

Mineral Statistics.

The Survey has undertaken the collection of mineral statistics for the year 1910, in co-operation with the U. S. Geological Survey. The statistics include complete totals of quantity and value for all metallic and non-metallic products of the state. As soon as the returns for any product have been received and tabulated the same will be distributed to the press of the state and the complete statistics for all the products will be issued in a separate publication of this department.

It is planned that the collection and publication of complete statistics of mineral production in the state will hereafter be an important and useful feature of the work of this department. A report bearing the statistics of mineral production should be issued on the following plan: (1) The report should appear promptly as soon as possible after the close of each year; (2) it should give complete statistics for all branches of the mining and allied industries, including metallic and non-metallic products; (3) it should be accompanied by maps and sketches giving location of mines, quarries, etc., and (4) it should contain a general resume for the year of mining conditions in the state, as nearly as possible by

districts and products, with special reference to new explorations and the bearing thereon of possible extensions of known mineral producing areas and discovery of new ones.

It is not to be expected that the first report, i. e., for 1910, will embody all of the above features but it is hoped that all of these will be included in subsequent reports.

Change in Form of Publication.

In a meeting of the Board of Scientific Advisers held April 8, 1910, there was considered a plant for improvement in the form and methods in use in the printing and binding of the reports of the Geological and Biological Survey. The plan which was adopted on the approval of the Board of Geological Survey, and also with the approval of the Board of State Auditors is outlined below:

(1) The plan of binding all of the reports of the Board of Geological Survey issued for one fiscal year under one separate cover shall be discontinued.

(2) The geologic and biologic reports shall be in no case bound together in the same volume.

(3) Reports, either geologic or biologic, dealing with closely related subjects, at the discretion of the Board of State Auditors, may be bound in one volume.

(4) Each separate volume, exclusive of the executive report of the Director, shall form one of a new series, in which the volumes shall be numbered consecutively in the order in which they are published.

(5) The administrative and executive report of the Director shall be issued annually as provided in Section 6, Chapter 55, Compiled Laws of Michigan 1897, and shall constitute, with other publications in a given year, the Annual Report of the Board of Geological Survey.

In addition to the above, the style and quality of the binding, the character of the print and the quality of the text and plate paper have been improved, to the end that now our reports are on a par with the best of those issued by the federal and other state geological surveys. Publications 1, 2 and 3 have already appeared under this new plan of publication.

Publications Issued Since September 1, 1909.

Annual report for 1908. Two volumes.

Volume 1. 402 pages. 3 plates. 6 figures.

Part 1. Administrative report of the State Geologist, A. C. Lane.

Part 2. Geological Section of Michigan for Geologists, Teachers and Drillers, by A. C. Lane and A. E. Seaman.

Part 3. Geology of Tuscola County by C. A. Davis.

Part 4. The Intrusive Rocks of Mt. Bohemia by F. E. Wright.

A part of the edition of Parts 2, 3 and 4 of Volume 1 are bound separately in paper covers.

Volume 2. An Ecological Survey of Isle Royale prepared under the direction of Chas. C. Adams. 63 plates and figures.

Annual report for 1909.

Publication 1, Biological Series 1. 95 pages. 17 plates.

Containing:

The Crawfishes of Michigan by A. S. Pearse.

The Insect Galls of Michigan by Mel T. Cook.

The Birds of School Girl's Glen by A. D. Tinker.

Preliminary List of the Sites of Aboriginal Remains in Michigan by Harlan I. Smith.

Publication 2, Geological Series 1. 248 pages. 33 plates. 9 figures.

The Monroe Formation of Southern Michigan and Adjoining Regions by A. W. Grabau and W. H. Sherzer.

Annual report for 1910.

Publication 3, Geological Series 2. 160 pages. 17 plates. 18 figures.

The Geology of the Iron River Iron Bearing District of Michigan by R. C. Allen.

Ready for Publication.

The Geology of the Copper Bearing Rocks of Michigan by A. C. Lane. 2 volumes.

The Geology of Arenac County by W. M. Gregory.

A Soil Map of the Upper Peninsula of Michigan. Scale 6 miles to the inch.

Earthquakes in Michigan by Prof. W. H. Hobbs.

In Preparation.

The Geology of Wayne County by W. H. Sherzer.

The Salt Industry of Michigan by C. W. Cook.

The General Geography of Michigan by L. H. Wood.

PROGRESS OF THE TOPOGRAPHIC SURVEY IN MICHIGAN.

The ultimate aim of the topographic survey in Michigan is the mapping of the entire area of the state, 57,980 square miles, in units of 15′ of latitude by 15′ of longitude, each unit being issued as a separate sheet on a scale of 1:62,500, except in certain areas where for special reasons a larger scale is more desirable.

When the survey is completed we shall possess a topographic atlas of the state which will consist of the unit quadrangles showing besides topography, all highways, railroads, trolley lines, the drainage, natural and artificial, and all permanent cultural features, including location of buildings at the time survey is made, bound together, with a key map on which the relative position of each separate sheet is indicated. It is not necessary to urge before this Academy the value of such an atlas of the state nor the urgent desirability of its completion at the earliest possible moment.

Up to the present time a total of 4,924 square miles, or about 8% of the area of the state has been surveyed including sixteen 15-minute sheets in the Lower Peninsula, and in the Upper Peninsula seven 15′ minute sheets, and four special sheets to accompany geologic maps of the iron districts, and the Calumet Special sheet. Of the work done in the Upper Peninsula all has been done at the expense of the U. S. Geo-

logical Survey, with the exception of the Marquette sheet which, with the 16 quadrangles in the Lower Peninsula has been made in co-operation with the Michigan Geological Survey.

For the fiscal year ending June 30, 1910, there was available for topographic work $4,000.00 of which amount half was appropriated by the state, and half by the U. S. Geological Survey. The Mason quadrangle in Ingham and Livingston counties was completed and work on the Lansing quadrangle in Ingham and Eaton counties was begun and about half finished.

Four thousand dollars of joint co-operative funds is available for the present fiscal year ending June 30, 1911. During the past summer field work on the Lansing quadrangle was completed and the map is now almost ready for the press. Field work on the Charlotte quadrangle will be begun in the spring and continued through the summer.

In addition to the $4,000.00 of co-operative funds there was appropriated, by the Director of the U. S. Geological Survey on the initiative and personal solicitation of the State Geologist, aided by our representatives in congress, $2,500.00 for topographic work in Michigan for the fiscal year 1910-11. This will largely increase the amount of work which could be done with the co-operative funds alone. However, I have no assurance that this, or even a smaller amount will be granted by the Federal Survey for a period of years, over and above the amount granted under the co-operative plan, although the appropriation was made initially to the beginning of work on four quadrangles in the Northern Peninsula which was requested by the Director to be undertaken at the expense of the Federal Survey.

The co-operative funds permit of the completion of about one and one-half 15-minute quadrangles per year, under the most favorable conditions. At this rate we shall complete the topographic atlas of the state in about 175 years. With ten times our state appropriation, i. e., $20,000.00 per annum, providing that a like amount is appropriated by the U. S. Geological Survey, I estimate that the work can be completed in 15 years. Twenty thousand dollars a year is, in my opinion, not too much to be annually appropriated by the state for this work. The Federal Survey stand ready to match any appropriation the legislature may grant up to $20.000.00.

Other states have outstripped Michigan in their efforts to complete a topographic atlas. The total area of five states has been surveyed, six others have surveyed 70% or more of their total area, 18 others have surveyed over 30%. Only four other states, viz.: Minnesota, Mississippi, Indiana and Florida have so little of their total area surveyed as has Michigan. Of these Florida has 3%, Minnesota and Mississippi each 4%, and Indiana 8%. No other state has greater need for a topographic survey than has Michigan, which in natural resources is second to few other equal areas on the continent.

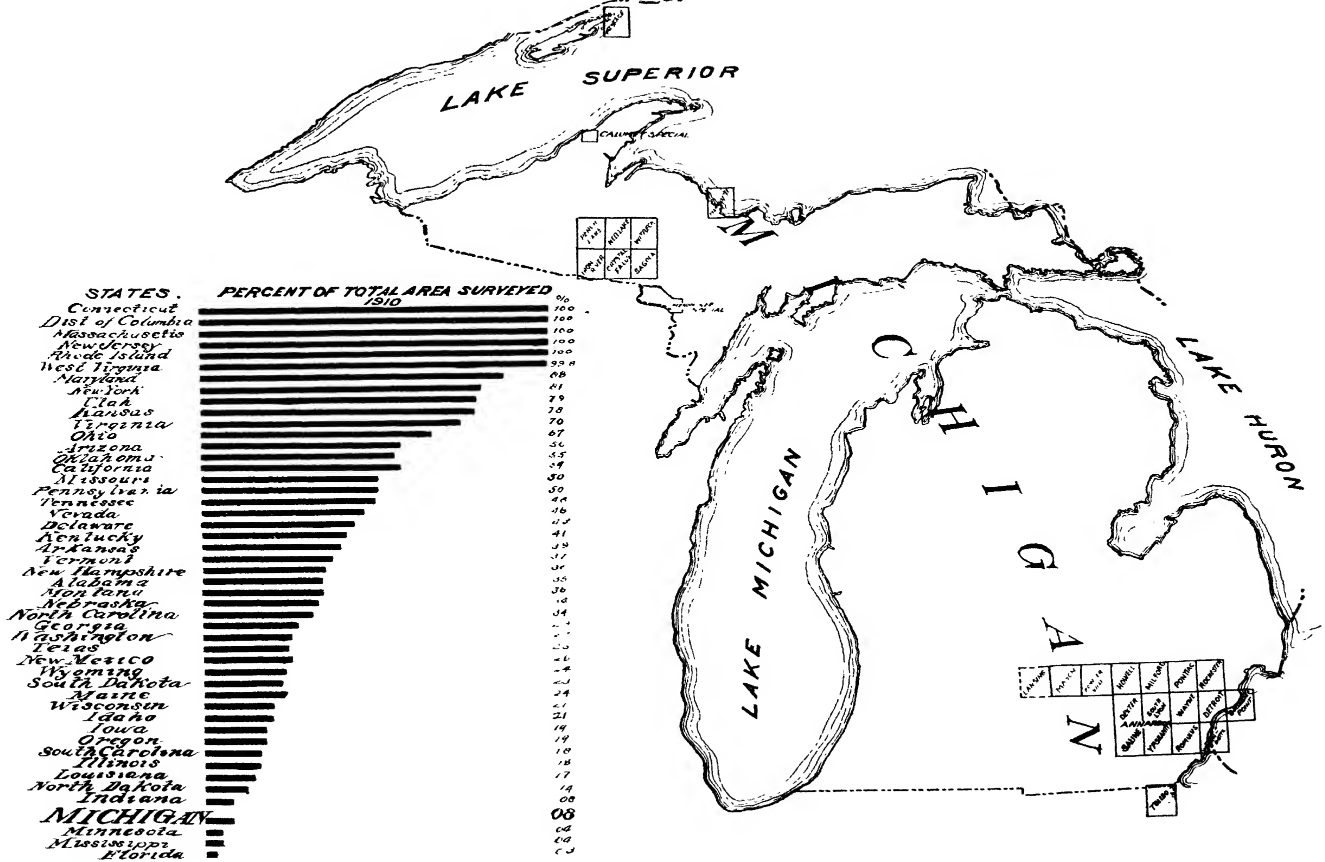
It will be seen by reference to the table below compiled from the annual report for 1910 of the Director of the U. S. Geological Survey, that of the states which co-operate with the Federal Survey in topographic mapping only one, Virginia, appropriates so small an amount per annum for this work as does Michigan, yet it should be noted in making this comparison that Virginia has surveyed 70% of her entire area and Michigan has surveyed only 8%.

TABLE SHOWING PROGRESS OF TOPOGRAPHIC SURVEY IN STATES IN WHICH THE STATE AND FEDERAL SURVEYS CO-OPERATE.

State.	State appropriation.	U. S. appropriation.	Surveyed in 1909-10. Square miles.	Total surveyed to July 1, 1910. Square miles.	Total areas surveyed to July 15, 1910, in per cent.
West Virginia	$15,000	$15,000	. .	24,120	99.8
Maryland.	3,000	4,000	321	10,771	88
New York	7,000	7,000	649	40,221	81
Virginia	1,750	1,750	....	29,980	70
Ohio.	15,000	15,000	2,022	27,319	67
California	14,000	14,000	8,183	92,914	59
Missouri	4,500	4,500	320	34,692	50
Pennsylvania	4,238	4,238	629	22,813	50
Kentucky	5,000	5,000	329	16,476	41
North Carolina	2,500	2,500	243	17,661	34
Washington	10,000	10,000	2,228	20,754	30
Texas.	20,000	20,000	493	66,807	25
Maine	3,500	3,500	402	7,801	24
Iowa.	1,750	1,750	182	10,448	19
Oregon	2,500	2,500	605	18,279	19
Illinois	17,500	12,500	1,136	10,082	18
Louisiana	20,000	6,700	300	8,283	17
Michigan	2,000	2,000	439	4,924	8
Minnesota	10,000	5,000	495	5,582	4

The slow progress of the topographic survey in this state is due to the failure of the legislature to appropriate money in proportion to the value and importance of the work, and in great measure to the apathy of the engineers, educators, and others who understand the utility and the importance of a completed topographic atlas from both the economic and the purely educational view points. It is necessary that the legislature be convinced of the importance and value of the topographic atlas before it will acquiesce in the expenditure of public money for its rapid completion. Let every resident member of the Michigan Academy of Science constitute himself a committee of one to take this matter up with the senator and representative from the district in which he lives urging the desirability of the early completion of the topographic atlas of the state and much will be done thereby toward securing an appropriation for this work in keeping with its value and importance to the development of the state.

PROGRESS OF TOPOGRAPHIC SURVEY IN MICHIGAN
COMPARED WITH OTHER STATES
1910.



BIOLOGY.

BY ALEXANDER G. RUTHVEN, CHIEF FIELD NATURALIST.

At the general meeting of the Michigan Academy of Science last year, I reported upon the progress of the biological work of the Survey up to that time.* I stated then that four papers were in press, six in preparation, and that a botanical investigation of an area on the west coast of Michigan was planned for the summer of 1910.

In June, 1910, Bulletin I, Biological Series 1, of the Survey was published. This report contained the following four papers:

Pearse, A. S.—The Crawfishes of Michigan, pp. 9-22, 8 plates.

Cook, Mel. T.—The Insects Galls of Michigan, pp. 23-33.

Tinker, A. D.—The Birds of the School Girl's Glen Region, Ann Arbor, Michigan. A study in Local Ornithology, pp. 35-66, 8 plates, 1 map.

Smith, Harlan I.—Preliminary List of the Sites of Aboriginal Remains in Michigan, pp. 67-89.

Four papers based upon survey material and published elsewhere than in our reports also appeared during the year. They are:

Baker, H. B.—Variation in Lymnaea Reflexa Say, from Huron County. 12th Ann. Rept. Mich. Acad. Sci., pp. 60-63.

Ruthven, Alexander G.—Notes on Michigan Reptiles and Amphibians, II. 12th Ann. Rept. Mich. Acad. Sci., p. 59.

Ruthven, Alexander G.—The Mershon Expedition to the Charity Islands, Lake Huron. Science, N. S., XXIII, pp. 208-209.

Pearse, A. S.—A Preliminary List of the Crustacea of Michigan. 12th Ann. Rept. Mich. Acad. Sci., pp. 68-76.

The last paper is to be ranked with our monographs, and was prepared by Dr. Pearse for our use.

I have investigated the status of the other manuscript papers mentioned in the April report, and find that substantial progress has been made in all of them. The report on the biological survey that was made of the sand region on the south shore of Saginaw Bay is in press, and the others will appear as rapidly as they can be finished and edited.

Manuscripts now in preparation that were not listed in the April report are mostly the results of work done last summer or under way at the present time. Dr. C. H. Kauffman reports that he and Dr. L. H. Pennington had excellent success last summer in the botanical work in the western part of the state. Dr. Kauffman was in the field from June 27 to September 30; Dr. Pennington from June 27 to August 27. The field work covered about 350 square miles in Allegan, Ottawa and Van Buren Counties, and copious notes and a large collection of specimens were secured as the basis of a report.

*12th Ann. Rept. Mich. Acad. Sci., pp. 54-58.

All of the money available from the survey appropriation for the year was put into the botanical work in the western part of the state, but, thanks to the generosity of Hon. W. B. Mershon, we were enabled to send out another party, to the Charity Islands, Saginaw Bay. Mr. Mershon bore the expense incidental to sending five men to the islands for different periods of time last summer, and as a result we were able to make quite an exhaustive investigation of the fauna and flora. The men that we sent up and the groups that they studied were as follows:

N. A. Wood (vertebrates), W. W. Newcomb (butterflies and moths), A. W. Andrews (beetles), Frederick Gaige (ants), and C. K. Dodge (plants). These men worked for their expenses, and to their enthusiasm and energy is due in large part the excellent results obtained. Large collections of the different groups were secured, together with voluminous notes on habitats, etc. The men are now working on their reports, which will be published in various journals under the general title "Results of the Mershon Expedition to the Charity Islands, Saginaw Bay." The first one, the general account, has already appeared, and the report on the birds, by Mr. Wood, will be published in the June number of the Wilson Bulletin.

In addition to the monographs listed in the last report, we have another in preparation, "The Amphibians of Michigan," by Crystal Thompson and Helen Thompson. This paper is now practically completed and awaiting publication. Two other very excellent papers that are awaiting publication are a catalog of the more recently described species of fresh-water mollusca, by Mr. Bryant Walker, and a bibliography of Michigan archeology, by Mr. Harlan I. Smith.

The work proposed for next year is as follows: A few weeks work on the Charity Islands in the early summer to supplement the late summer and early fall work of last year, a preliminary investigation of the mammals in the region of Osceola county, and the collecting of botanical material from various parts of Michigan for a state herbarium.

In closing I would like to make a plea for more cooperation on the part of the members of the Academy. It is of the first importance to us to have exhaustive data on the occurrence of each species within our limits, but we have experienced considerable difficulty in securing such material. From no region have we enough data, and from many regions we have few or no records for most groups. Thus any records of occurrence, even though they are of our commonest forms, are valuable. I wish every teacher of biology, or other interested person, in the state would get into the habit of sending us such specimens or notes as they have the opportunity to obtain. We maintain a record bureau at the Museum, and every reliable record received is preserved, whether or not it comes to us with a specimen.

PRELIMINARY REPORT ON THE SALT INDUSTRY OF MICHIGAN.*

C. W. COOK.

The salt industry of Michigan has had a long and varied history. Before the admission of Michigan into the Union, attempts were made to manufacture salt from the saline waters of springs, both in Macomb county and at Saline in Washtenaw county. The statehood act of 1836 permitted the reservation by the state of seventy-two sections of saline lands and for the next twenty odd years numerous endeavors were made to develop these salt springs. However, the efforts met with continual failure and the lands were finally disposed of.

A small amount of salt was manufactured, in 1842, at Grand Rapids by the Hon. Lucius Lyon.[1] The price of three dollars per barrel, obtained at this time, enabled him to operate without loss but at no profit and the attempt was soon abandoned.

The real beginning of the industry dates from 1859, when the first successful well was sunk at East Saginaw by the East Saginaw Salt Manufacturing Co. From then until the present, the growth has been practically continuous, until, in 1905, Michigan assumed first place in production, and in 1908, passed all other states in the value of the produce.

This progress has been marked by the rise and fall of various districts. The Saginaw Valley, with the industry centered at Saginaw and Bay City, became the first important district. From here, the industry soon spread to Midland, St. Louis, and the towns along the lake shore, such as Caseville, Pt. Crescent, Pt. Austin, New River, Pt. Hope, Harbor Beach, and White Rock on the south side of Saginaw Bay; and Tawas City, East Tawas, Oscoda, and Au Sable to the north.

These plants first used the kettle process. It soon gave way, however, to the open pan and grainer. Most of the salt blocks were operated in connection with sawmills, the refuse (saw-dust and slabs) being used for fuel in the kettle and pan blocks, while exhause steam was employed in the grainers. This undoubtedly lead to the waste of a large amount of lumber. As one former operator told me, "Give us plenty of saw-dust and slabs, we don't care for the lumber" was a common saying.

The dependence of salt upon the lumber industry is shown by the disappearance of all of the lake shore plants. In fact, even some of the towns, such as Pt. Crescent and New River, are now but memories. In the Saginaw Valley itself the industry is fast disappearing, so that, where once there were over one hundred plants in operation, now but nine, including a small plant at Mt. Pleasant, remain.

Correlative with the decline of the Saginaw Valley industry, has

*Published with the permission of the State Geologist.

[1]Winchell, A., "On the Saliferous Rock and Salt Springs of Mich." Am. Jour. Sc. Vol. 34, 2nd series, 1862, p. 309.

been the rise of the Ludington-Manistee district, and the region along the Detroit and St. Clair rivers.

At present, the Ludington-Manistee district leads in production, having produced, in 1909[1], two-thirds of the entire output of the state. Here the industry is likewise associated with the lumber industry, but one plant, the Anchor Salt Co., of Ludington, operating independently of the saw-mills. Two processes are in use, the grainer and the vacuum pan, and the product, which is sold largely in bulk and barrels, is what is known as common salt in counter distinction to table salt. The Stearns Salt and Lumber Co. of Ludington, however, is planning to install apparatus for the manufacture of table salt.

The first attempt, in later years, to manufacture salt in the Detroit-St. Clair Rivers district was made at Mt. Clemens. While this effort was a failure, owing to the fact that the well did not pierce the rock salt but stopped in a brine-bearing stratum above, the brine of which was too impure to be successfully utilized in the manufacture of salt, it is especially interesting in that it lead to the discovery of the remarkable curative properties of the Mt. Clemens mineral waters.

When later rock salt was found, plants were established at many points along the St. Clair River, and then south of Detroit. So that today, companies are operating at Pt. Huron, St. Clair, Marine City, Delray, Ecorse, Wyandotte and Oakwood. In addition to these brine plants, rock salt is being mined at Oakwood by the Detroit Salt Co. In this district, all types of manufacture, employed in Michigan, may be seen. Thus we find the open pan, grainer, vacuum pan, and Alsberger systems all in operation. The majority of the plants also make table salt.

With the exception of the rocksalt produced at Oakwood, salt is manufactured in Michigan by the evaporation of brines, both natural and artificial. At various times, three different natural brines, each of which is obtained from a sandstone, has been employed. These brine-bearing sandstones are the Parma, the Napoleon, and the Berea.

The Parma brine, while no longer used on account of its being weaker than the underlying Napoleon brine, is characterized by its purity. As may be seen from the analyses in table I, it is distinguished from the Napoleon and Bera brines by a higher percentage of calcium sulphate relatively to the early chlorides. This brine was one of the first used in Michigan and its utilization was limited to the Saginaw Valley.

[1]Report State Salt Inspector, 1909.

TABLE I.

	1.	2.	3.	4.	5.
Calcium sulphate	3,961	. . .	.	0.129	0.33
Calcium chloride	5 302	41 1	83 00	31 274	110.00
Magnesium chloride	4.115	17 6	31.00	15 675	33.47
Magnesium bromide	. .	0.712	1	. .	. . .
Ferric oxide and Alumina	. .	. .	. .	. . .	1.14
Ferrous chloride	. .	0 050	Trace	. .	.
Sodium chloride	152.674	167 3	141 00	176.161	186.19
Total solids	166 052	226 675	256.00	232 803	331 73

1, 2, 3, and 4 represents grams per kilogram.
5 represents grams per litre.
1. Parma brine from Gilmore well, Bay City, Michigan. Analysis by Dr. A. C. Goesmann, October, 1862. (Geol. Sur. of Mich. Vol. III, p. 181.)
2. Napoleon brine from Saginaw Salt Co., St. Charles, Michigan. Analysis by J. C. Graves, furnished by O. C. Diehl.
3. Marshall brine from the Dow Chemical Co., Midland, Michigan. Analysis furnished by H. W. Dow.
4. Per a brine from the Ayres well, Pt. Austin, Michigan. (Geol. Sur. of Mich., Vol. III, p. 183.)
5. Berea brine from the North American Chemical Co., Bay City, Michigan. (Geol. Sur. of Mich. report for 1905, p. 388.)

The Napoleon brines (Nos. 2 and 3, table I) which are the source of the salt of the Saginaw Valley, are characterized by the small percentage of calcium sulphate and the presence of considerable amounts of bromine. It will be noted that the amount of bromine and earthy chlorides increases relatively to the sodium chloride as we go toward the center of the basin. While no analyses are available, Dr. Dow informs me that there is a considerable increase at Mt. Pleasant over Midland.

The Napoleon sandstone is found at a depth of about 650-800 feet at Saginaw, 800 feet at Bay City, 1,300 feet at Midland, and 1,400 feet at Mt. Pleasant.

Besides salt, a number of other products are obtained from this brine. The Dow Chemical Co. of Midland manufactures a large number of chemicals, among which may be mentioned, bromine, bromides, bleaching powder, and chloroform; the Van Schaak Calcium Works of Mt. Pleasant produces bromine and calcium chloride; the Saginaw Plate Glass Co. has recently installed apparatus to recover the calcium chloride from the mother liquors from the salt block; and the North American Chemical Co. of Bay City uses the brine in the preparation of chlorates.

The Berea brine (Nos. 4 and 5, table I) was used by the plants along the lake shore in Huron and Iosco counties. It contains an appreciable amount of bromine, not shown in the analyses, which was recovered from the bittern at some of the plants.

There are other Michigan brines, which, although they have not been used for the manufacture of salt, are, at present, attracting considerable attention on account of their high content of potassium. Of these, two may be mentioned. The first is from the deep well at Harbor Beach. It is found at a depth of 1875 feet in what Lane[1] has called the Monroe formation with a question mark. The second is from Muskegon. It is struck at a depth of 2,030 feet in what is probably the Dundee limestone. The analyses follow:

[1]Geol. Sur. of Mich., Vol. V, Part II, p. 82.

	1. Grams per liter.	2. Grams per kilogram.
Calcium sulphate	9936	4.22
Calcium chloride	62.6636	54.10
Magnesium chloride	5 3542	14.97
Magnesium bromide	24 8400	2.37
Potassium chloride	37.7788	22.16
Sodium chloride	179 2391	158.17
Silica	7303	....
Total solids	311 5996	255 95

1. Brine from well of the Sand Beach Mineral Springs Co., Harbor Beach, Michigan. Analysis by S. P. Duffield. (Geol. Sur. of Mich., Vol. V, Part II, p. 82.)
2. Brine from the Ryerson well, Muskegon, Michigan. Analysis by Dr. C. A. Goesmann, September, 1883. (Geol. Sur. of Mich., report for 1901, p. 233.)

The artificial brines, employed in the Ludington-Manistee and Detroit-St. Clair rivers districts, are formed by solution of the rock salt of the Salina formation. In the former the flow of ground water in the super-imposed strata is sufficient to form the brine and the pumping is done mostly with compressed air. At most of the plants in the southeastern part of the state, it is necessary to pump water into the wells and the brine when formed is forced up by water pressure.

At Ludington and Manistee the salt layer has a thickness of 20 to 30 feet and is found at a depth of about 1900 feet at Manistee and 2,300 feet at Ludington. It has been thought that but one bed existed in this district.[1] However, the No. 4 well of the Anchor Salt Co. at Ludington shows the presence of four beds, respectively 20, 12, 7, and 5 feet in thickness. The extent of this area is not known, but wells at Frankfort and Muskegon, which should have pierced it had it been present, failed to disclose any salt.

The salt beds of the southeastern area are much greater both in number and thickness, one being over 250 feet thick. In a general way they seem to dip away from the Cincinnati anticline and to increase in thickness along the dip. How far this increase continues we do not know, as no records are available beyond Royal Oak, where nine beds have an aggregate thickness of 609 feet.

Another area in which rock salt has been found in considerable quantities, but has not, as yet, been exploited, is in the vicinity of Alpena. Five beds of salt with streaks of anhydrite here show an aggregate thickness of over 300 feet.

Although we have no positive evidence on the subject, from a consideration of the general geology of the state and the apparent increase in thickness of the beds along the dip, it seems reasonable to believe that these three areas are but portions of one larger area. Rock salt is therefore likely to be found anywhere within lines joining the outer limits of the different proved areas.

The composition of the brines may be seen from the following analyses:

[1]Lane, Report for 1908, p. 59.

	1.	2.
Specific gravity	1.138	....
Calcium sulphate	5.66	2.3
Calcium chloride	....	1.0
Magnesium sulphate	....	....
Magnesium chloride	2.015	0.7
Sodium chloride	247.4	265.7
Total solids	255.075	269.7

The above represents grams per kilogram.
1. Filer and Sons, Filer City, Michigan. Analysis by W. and H. Heim, Saginaw, Michigan. Analysis furnished by Mr. E. G. Filer.
2. Michigan Salt Co., Marine City, Michigan. Analysis by Robt. E. Devine, Detroit, Michigan. Analysis furnished by Mr. S. C. McLouth.

As to the methods of manufacture, one, the open pan, employs direct heat, the others use steam, either live or exhaust.

The open pan system may be thus briefly described. The pans, which are constructed of boiler plate, are about seventy feet long, twenty-five feet wide, and twelve inches deep, and have sloping sides to permit of the salt being raked onto the draining boards. The heat is furnished by a furnace placed at one end, the pan above being protected by a brick arch. The heated gases pass back under the pan to the chimney. In some cases, the chimney is placed beside the furnace, the gases, by means of a return flue, being made to traverse the length of the pan twice.

The grainer consists of a rectangular vat, 100-160 feet long, 8-18 feet wide, and 22 inches deep, in which are placed steam pipes. The salt when formed is removed either by hand with shovels or by automatic rakers.

The vacuum pan consists of a vertical steel cylinder tapering at both ends, in the middle of which is a steam belt, through which the brine tubes pass, with a large tube in the center. A partial vacuum is maintained in the pan so that the boiling point of the brine is considerably lowered. If the pan is run "single effect," the steam formed by the evaporation of the brine is taken care of by a condenser. On the other hand, when two or more pans are run in "multiple effect" the steam formed in the first pan is conducted to the belt of the second pan on which a greater vacuum is carried and is used to furnish the heat for the second pan. The "triple effect" pan is in successful operation at a number of Michigan plants, and in New York state a "quadruple effect" is being operated. The salt, as it forms, drops to the bottom of the pan and is removed by a bucket elevator.

With respect to the Alsberger system, I shall not go into details but merely state that the principle involved is that of superheating the brine under pressure and then running it into pans in which the deposition of the salt takes place without the further addition of heat. Revolving rakers scrape the salt into a well from the bottom of which it is drawn off into a centrifuge in the form of a paste and separated from the water.

In the manufacture of table salt, the common salt is dried by passing it through a rotary kiln. The dried product is then separated into the

different sizes, such as table, butter, cheese, etc., by means of tubular screens or patent separators. To some of the fancy brands of table salt small amounts of calcium or magnesium carborate are added to prevent caking.

The salt production of the state for 1908, as given by the U. S. Geological Survey, was 10,194,279 barrels valued at $2,458,303. This includes the brine salt worked up into soda ash and other products. The production for the same year as given by the state salt inspector was 6,247,073 barrels.

Ann Arbor, Mich., April, 1911.

THE EXTENT OF THE ANDERDON BEDS OF ESSEX COUNTY, ONTARIO, AND THEIR PLACE IN THE GEOLOGIC COLUMN.

REV'D THOMAS NATTRESS.

Considerable interest has centered in the Anderdon Limestone Beds of Anderdon Township, Essex County, Ontario, since Garbau pronounced them hitherto unrecognized in 1907 and gave to the beds the name they now bear. That interest was intensified by Professors Sherzer and Grabau when they claimed to have identified this limestone with certain problematical beds deep down in the Silurian strata in the Salt Shaft at South Detroit.

A year ago in presenting before the Academy a paper on The Contour of the Sylvania Sandrock and Related Strata in the Detroit River Area, I took occasion to adduce some suggestive evidence that the supposed intercalated beds at the salt shaft and the Anderdon beds have each their own independent horizon.

Since then it has fallen to my lot to superintend the taking out of thirty drill cores to determine the extent of these limestone beds in Anderdon and Malden townships. Ten other cores had already been taken out in and near the Amherstburg Quarries in Anderdon. In addition to these forty drill cores, there are three quarry holes through the high grade limestone, to facilitate the estimate. The accumulated evidence has too broad a bearing not to be presented in the endeavor that has been yours and mine to solve the problems of the Detroit river area.

Professor Grabau has himself differentiated the Anderdon limestone in his Stratigraphic and Palaeontologic Summary of the Monroe Formation. Under the head of *"Upper Monroe Faunas" he groups as a unit the faunas of the Flat Rock, Anderdon and Amherstburg (Detroit river bottom) beds. Of the faunas of this supposed unit he has said: "Its most characteristic feature is its Devonic element." And: "If the fauna were considered by itself it would probably be pronounced a Scoharie or an Onondaga fauna without a moments hesitation, though there is a considerable Siluric element."

Taking the cut on p. 541 of the "Proceedings of the Albuquerque Meeting, (Fig. I. — Section of the Detroit river)," as setting forth the supposed relationship of the "Flat Rock, Anderdon coral limestone and Amherstburg Dolomite," the Flat Rock below, the Amherstburg Dolomite above, the Anderdon between, —— then the "considerable Siluric element" ought to be very evident in the sandwiched Anderdon limestone in order that it should still persist in the overlying new-named Amherstburg. But whereas the Siluric fauna characterizes the Flat Rock and the Amherstburg Dolomite of the Detroit river bottom, it is characteristically absent from the Anderdon limestone beds.

Moreover, the Anderdon beds do *not* extend across Detroit river from

*The Monroe Formation; Mich. Geolog. and Biolog. Survey, 1909, p 217.

the Amherstburg quarry to the Sibley quarry as figured in the cut referred to. This I have contended before and shall be able to set forth further evidence. The Dundee (Corniferous) limestone does *not* extend westward to the Detroit river as thus figured, and *does* form the surface extension over the great part of the Amherstburg quarry in Anderdon, where the cut shows only Anderdon coral limestone —— out of relation.

Analyzing Grabau's faunal unit, this result is obtained:

Flat Rock Dolomite:

Stromatoporoidea, 0.	*Anthozoa*, 3.
Brachiopoda, 0.	*Bryozoa*, 0.
Pelecypoda, 0.	*Gastropoda*, 0.
Cephalopoda, 0.	*Trilobitae*, 0.
Annelida, 0.	

The Anderdon Limestone:

Stromatoporoidea, 6.	*Anthozoa*, 12.
Brachiopoda, 2.	*Bryozoa*, 0.
Pelecypoda, 1.	*Gastropoda*, 2.
Cephalopoda, 0.	*Trilobitae*, 0.
Annelida, 0.	

The Amherstburg Bed (dolomite) of Detroit River:

Stromatoporoidea, 2.	*Anthozoa*, 13.
Brachiopoda, 12.	*Bryozoa*, 1.
Pelecypoda, 3.	*Gastropoda*, 8.
Cephalopoda, 4.	*Trilobitae*, 1.
Annelida, 1.	

Of the *Stromatoporoidea* 2 of 6 are in common between the Anderdon limestone and the Amherstburg dolomite.

Of *Anthozoa* there is 1 in common throughout, and but 4 in common between the Anderdon limestone and the Amherstburg dolomite, out of a total of 21.

Of *Brachiopoda* there is but 1 of 13 in common between the Anderdon limestone and the Amherstburg dolomite.

Bryozoa is represented in the Amherstburg dolomite alone.

Of *Pelecypoda* but 1 out of 3 is in common between the Anderdon and the Amherstburg.

Of *Gastropoda* there is nothing in common, though 10 species have been noted.

Cephalopoda, Trilobitae and *Annelida* are represented in the Amherstburg only, in *Grabau's list. I have since found *Proetus crassimarginatus,* in the Anderdon limestone.

I submit that here is an internally exclusive "unit."

Nor is that the end of the comparison. Of 23 species (5 genera) identified in the Anderdon limestone and the coral bed of the salt shaft at

*Michigan Geological and Biological Survey, 1909, The Monroe Formation, —— Grabau and Sherzer.

Delray, but 7 are in common to these, one only of which is found in the dolomite of the Detroit river bed in the vicinity of Amherstburg.

Having presented *evidence to show what the Anderdon limestone beds are not, I shall attempt to show what these beds are,—how they are deposited, and how they are related.

THE MALDEN VALLEY.

The drill holes put down to determine the extent of the Anderdon limestone have disclosed a basin and a valley leading to it from the south, together containing the "Anderdon Beds" (Grabau). I have presumed to name this valley the Malden Valley of the Anderdon Limestone, inasmuch as it was first followed up from a starting point in Malden township. I have followed up this valley some 6,500 feet from that starting point of investigation to where it expands into a basin, the central area of which is the Amherstburg Quarry property.

Cross sections prove the valley formation and show the relation of the Anderdon Beds to the underlying Silurian dolomites. A complete cross section is constituted by test holes numbered 9 to 13, from east to west.

In No. 9, in an old Detroit river channel, there is a Silurian surface extension. Analyses show an average of 56.75 $CaCO_3$.

About 800 feet west of it No. 10 showed Anderdon Beds at the surface, one foot in depth, resting upon a transitional rock, which in turn rests upon Silurian dolomite. The transitional here averages 60.56 $CaCO_3$, and is 8 feet in depth; the dolomite 54.19 tested to a depth of 21 feet.

No. 11 is about 700 feet west of No. 10: Anderdon 13 feet, averaging 93.76 $CaCO_3$; Transitional, 8′ 6″, 63.37; Silurian dolomite 5′ 10″, 54.87.

No. 12, about 700 feet west of No. 11, shows 10′ 7″ of Anderdon, averaging 95.60 $CaCO_3$; Transitional, 7′ 9″, 62.44; dolomite not penetrated.

No. 13 is about 700 feet of No. 12. Here there is but 2 feet of Anderdon Beds, averaging 94.72 $CaCO_3$; Transitional 7′ 5″, averaging 57.53; Silurian dolomite penetrated 11′ 7″, averaging 50.39 $CaCO_3$.

Some 6,000 feet west of No. 13 is the Detroit river bed, with Silurian dolomite extension,—a surface that would probably extend as a surface extension as far east of Detroit river as to a point 300′ to 400′ west of No. 13 test hole.

A review of this cross section shows:

(1) The Anderdon Beds in the Malden Valley banking up against Silurian dolomite, east and west;

(2) A Silurian surface extension both east and west of the Anderdon Beds, in the old Detroit river channel eastward and in the bed of the present Detroit river westward; and, on reference to elevations,

(3) A Silurian dolomite synclinal between the Canadian channel of Detroit river immediately opposite Amherstburg (elevation 552.5 +) and No. 10 test hole, (elevation of Silurian surface, 563.2) in close proximity to the eastern edge of the Anderdon;

(4) A similar syncline east of that again, immediately; (5) Disturbance of former levels prevailing during the time of depositing of the

*See Michigan Academy of Science report, 1910. "The Contour of the Sylvania Sandrock and Related Strata in the Detroit River Area."

Transitional overlying the dolomite, during which time the present Silurian syncline was at least 700 feet wider than it is now, on the east side—for within that approximate distance the Transitional (of which there is 8 feet in depth at No. 10 hole,) has shored up;

(6) Maximum thrust of uplift in close neighborhood of No. 10;

(7) Change in elevations across the whole cross section distance of the Anderdon beds, with possible exception of the extreme western shore; and

(8) Suggests the reason for the prevailing increased depths of boulder till from the eastern limit of the Malden Valley of Anderdon limestone, westward to Detroit river,—an ascertained increase of depth of from 12′ 0″ to 15′ 6″ to 21′ 3″ to 28′ 6″ to 40′ 0″ at intervals of about 700 feet.

TRANSITIONAL ROCK.

The characteristics of the Transitional rock at the base of the Anderdon limestone, and the reasons for describing it as transitional are these:

(1) It lies between a limestone deposit of the purest quality and an equally pronounced Silurian dolomite, and is itself a dolomitic limestone.

(2) It is not local but extends over the whole area of, and beyond the outer edges of, the overlying Anderdon limestone; requiring, therefore, consideration as a distinct deposit; and having characteristics that relate it to both the Devonian and the Silurian.

(3) Like the Anderdon limestone above it, this rock carries the Devonian form of calcium carbonate crystal, dog-tooth spar, by contrast with the Silurian scalenohedra of calcite.

(4) Yet, in several instances, and at low horizons in the formation the crystals filling the cavities of the rock appeared to be a compromise between the two forms.

(5) In addition to that fact, the prevailing browns, blue-grays, and the dullness of the grays and drabs are Silurian characteristics.

(6) There were no Silurian forms distinguishable, nor either sulphate or carbonate of strontia, nor any gashed or acicular rock; all of which, with scalenohedra of calcite and high magnesia characterize the underlying strata.

(7) There is, as in the Silurian, at many elevations, considerable dark-lined lamination and frequent irregular lines of deposit.

(8) In three instances only does the $CaCO_3$ average of the transitional rock from a given test hole fall below 60%, and that where too few samples were taken. From all the rest of twenty-one averages the percentage of calcium carbonate is from 60.56 to 69.04. The average over all—in a distance of two miles—is 63.49 $CaCO_3$. This fact establishes the Transitional as a better calcium carbonate rock than is the heavy-bedded dolomitic limestone which lies second above it and forms the base of the Corniferous. This latter dolomitic limestone analyses about 60% $CaCO_3$. Like it, the Transitional appears to be almost fossil free.

I submit that this rock is transitional in character, with predominating Devonic features.

Before considering the question of transitional rock at further length let me present some facts of

THE BASIN OF ANDERDON LIMESTONE,

of which the Amherstburg quarry property forms the central area.

Thus far—except in viewing the entire distance of the Transitional—only the Malden Valley of Anderdon beds has been considered, by way of which the supply of this limestone seems to have come in from the south'ard.

The Amherstburg Quarry basin of Anderdon limestone is an expansion of the Malden Valley, circular in form, with a bulging western side. It seems to have had no other communication with the outer sea, in Anderdon time, than this valley. Cross sections will show the manner of deposit to best advantage. Two will suffice, one from east to west, and one from N. x NW. to S. x SE. Test* holes 26, "3," "8," and 21 are from east to west in order. No. "8" is as nearly as may be the center of the basin. No. 26 marks the eastern limit of the deposit, No. 21 is 1,500 feet west of this center and No. "3" is 1,350 feet east of center. Were there one more test made as far west of center as No. 26 is east of it, at the rate at which the depth lessens westward there would probably be about the same depth of Anderdon beds in that as there is in No. 26.

No. 20 test was the most westerly put down and though somewhat out of line for this cross section is yet available for comparison. (It is also interesting as establishing a bulging west side.)

Anderdon at 26, 1′ 3″,
Anderdon at "3," 16′ 7″,
Anderdon at "8," 28′ 0″,
Anderdon at 21, 15′ 9″,
Anderdon at 20, 6′ 2″.

This section shows an east and west shoreing up of Anderdon high grade limestone.

A MODIFIED ANDERDON.

During Anderdon time, and while these beds were being deposited, extraneous influences were exerted upon the Anderdon material about the outer edges of the basin, sometimes reaching across its full width—or rather would I say, meeting in the centre. Just what these influences were is not so easy to say. The effect exerted is very palpable. In some cases several feet in depth of the Anderdon beds are reduced to the quality of an ordinary good limestone; in other cases a silicated limestone was produced; in still other cases the slow depositing limestone has been swamped with magnesia and silica until a dolomite resulted. Whether the magnesia and silica were due to an inwash from a Silurian sea to the west, north, northeast and east, facilitated by a lowering of the confining Silurian anticlinal dam by earth movements from time to time, alternating with unlift; or whether the source of the extraneous matter was a Silurian land area, may be open to question. Very considerable depths of unmodified pure Anderdon limestone alternate with deteriorated parts. Especially is this true toward

*Plain figures indicate tests of the survey of Sept. to Dec., 1910; figures in quotation indicate tests of 1909 survey.

the centre of the basin, indicating that the influence was one felt chiefly along shore.

The silication is not so difficult to account for. In part it is from the same source without doubt. But when it is observed that the most heavily silicated spots are on the shoulders of the Malden Valley where it expands into the basin, and also directly in line with the slight wash from the inflow of the valley, the chief cause of silication has been identified. The valley itself has felt none of these influences to any perceptible degree.

Should it be that the magnesian influence was due to the sea, then it follows that Silurian conditions prevailed northward, westward and to the northeast whilst the Malden Valley communicated with a sea to the south in which Devonian conditions had already become established.

A N. x N. NW. to S. x S. SE. Cross Section shows the same basin formation, with No. "8" test hole as centre, four tests to the southeastward of it and two to the northwestward. (In no case has the west side been tested out to the same extent as the rest of the area, because of heavily increased depth of boulder till.)

The test holes of this cross section are, in order from S. x S. SE. to N. x N. NW., Nos. 15, 17, 22, "9," "8," "4" and "5." The distances between, in same order, approximately 1,000′, 450′, 425′, 525′, 1,725′, and 330′.

Anderdon at 15, 0′ ½″,
Anderdon at 17, 5′ 6″,
Anderdon at 22, 23′ 6″,
Anderdon at "9," 42′ 0″,
Anderdon at "8," 28′ 0″,
Anderdon at "4," 11′ 3″,
Anderdon at "5," 8′ 6″.

Modified Anderdon at 15, 0′ 0″,
Modified Anderdon at 17, 22′ 1″,
Modified Anderdon at 22, 22′ 10″,
Modified Anderdon at "9" 9′ 0″,
Modified Anderdon at "8" 23′ 6″,
Modified Anderdon at "4" 29′ 4″
Modified Anderdon at "5" 27′ 0″.

Transitional Rock at 15, 3′ 8″,
Transitional Rock at 17, 10′ 6″,
Transitional Rock at 22, 4′ 6″ +,
Transitional Rock at "9" 8′ 0″,
Transitional Rock at "8" 11′ 6″,
Transitional Rock at "4" 4′ 8″,
Transitional Rock at "5" Not penetrated.

The Anderdon shows distinctly the basin shape of deposit. On comparing the Anderdon + Modified Anderdon depths in No. "8" and No. "9," it will be noted that No. "9" has felt the deteriorating influences much less than the No. "8" area. It shows less Modified Anderdon and more high-grade limestone. Consequently, whether at base or sur-

face, the Modified Anderdon also shows the basin form of deposit in the cross section.

A consideration of the elevations in the same test holes in the same order gives the same results:

Elevation of Anderdon at 15, 570.36 A. T.
at 17, 570.63,
at 22, 566.00,
at "9," 558.26,
at "8," 547.50,
at "4," 576.15, and
at "5," 563.80;

Elevation of Modified Anderdon:
at 17, 565.13,
at 22, 543.50,
at "9," 526.26,
at "8," 519.50,
at "4," 564.90, and
at "5," 553.30;

Elevation of Transitional Rock:
at 15, 570.32,
at 17, 543.05,
at 22, 519.66,
at "9," 507.26,
at "8," 496.00,
at "4," 535.56,
at "5," not penetrated.

The basin, as shown by elevations of the Anderdon at No. 15 and No. "5"—has a lip rim, occasioned by uplift of the inner area in relation to the outer.

The evenness of the basin shape is evident if it be remembered that the distance from No. "8" to No. "4," 1,725 feet, is more than three times any other separating distance; that Nos. 17 and 15 are 1,000 feet apart; and that another test is needed about 350 feet N. x N. NW. of No. "5" to contrast with No. 15 at extreme S. x S. SE., for a complete comparison.

A cross section from NE. to SW., from the Sol White quarry hole, by way of the Amherstburg quarry limestone cut, test holes No. "8" and No. "7," to No. 20 shows the same basin-shaped deposit.

EARTH MOVEMENTS OVER THE ANDERDON AREA.

The evidences of earth movement over the Anderdon limestone area during Transitional, Anderdon and Corniferous time are of very pronounced character.

Included in the transitional rock shown up by cross section of the Malden Valley already presented, is a deposit characterized by quantities of calcium carbonate crystal, in bulk, so to say. In drill core No. 10 this is 48 inches in depth; in No. 11, 700 feet west it is 36 inches in depth; in No. 12, 700 feet west of No. 11, there is but 26 inches; and

in another 700 feet it has disappeared. This assuredly indicates one of two things: a deep side to the valley—which does not seem to account for all the facts in the case; or a gradual change of elevation during continuance of the deposit.

Subsequent to Anderdon time, and in what has hitherto been recognized as mid-Corniferous, a movement of a different kind has taken place. This time it is not tilting, but there appears to have been a thrust that reached its maximum along the eastern side of the Anderdon deposit—both valley and basin. The evidence is of two kinds: (1) *Change of elevation along cross section lines, and (2) a shattered condition of the eastern edge of the deposit. Every cross section shows a gradual slope to westward across the entire width of what must, in the order of things, have been a slightly concaved surface at the close of Anderdon time. In the Amherstburg quarry basin of the Anderdon material this movement is evidenced by relative differences of elevation, though the basin surface is still preserved in any but an east and west section.

SINK HOLES.

The shattered condition of the eastern edge of the Anderdon deposit is evidenced by a series of twenty or more sink holes in the land surface. In localities these are grouped together in numbers. In every case where the rock below has been investigated it has been found to be fissured and broken. Along the west side of the deposit the depth of stripping impervious to water would in itself explain the absence of sink holes. There does not, however, appear to be the same shattered condition of the rock, though the core-drill occasionally revealed a crack.

A LINE OF FAULT.

Associated with this line of sink-holes, and parallel with it, is a series of mineral springs highly charged with sulphur, that would seem to show a line of fault. This line traverses the old Detroit river channel immediately east of the Malden Valley of Anderdon limestone where the surface extension is entirely of Silurian dolomite.

THE MAXIMUM OF THRUST.

When the depositing of Anderdon sediment ceased, it would seem to be evidenced by a maximum depth of overlying Corniferous that the lowest elevation within the Anderdon basin—and approximately the center of the basin—corresponded closely with No. "8" test hole, at which spot there is still the lowest elevation (547.50) of Anderdon within the basin.

And at this precise spot the Corniferous has a higher elevation than any other part of the entire surface in question—unless it be between No. "8" and No. "9" which, together with it, has felt the maximum of thrust. The disturbed elevation of the Corniferous surface of itself proves

*Test holes 10 to 13, 2100 feet from east to west, show elevations of Anderdon beds: 571.30, 567.80, 561.85, and 554.50.

Test holes 29 and 27, in east to west section, 700 feet, show 574.40 and 563.90. Nos. 15 and 16, 780 feet east to west, 570.36 and 565.70. Test holes "1," "9," "7," and 19 and 20 show 574,33, 558.25, 538.10, 536.66 and 536.66.

earth movement. (Ascertained elevations: 578.26, 584.50, 561.10, 555.60, and 538.00.)

If there has been any earth movement strictly within Anderdon time the evidence is to be found in the Modified Anderdon. If that modification was due to movement and not to the influence of an adjacent land area round about the basin, then it proves in that case a successive lowering and raising of the surrounding Silurian dam that confined the Anderdon waters and excluded—except by intervals—the waters of a sea in which older conditions still persisted.

THE DEPTH OF BOULDER TILL.

The depth of boulder till on the Detroit river side of the line of highest elevations throughout the length of the Anderdon deposit, stands definitely related to the interposed rock barrier to the ice sheet in its forward movement. From east to west across the basin, 3,300 feet, the *depths of till are these:

10′ 2″, 14′ 0″, 21′ 6″, 32′ 6″, 50′ 0″.

Along the †complete cross section of the valley, east to west 2,100 feet: 12′ 0″, 15′ 6″, 21′ 3″, 28′ 6″, and, in another 1,000 feet westward along the Silurian dolomite surface, 40′ 0″.

On the other hand the glacial detritus has banked up against this same barrier on the east side of it, giving depths in ‡reverse order: 28′ 6″, and 10′ 2″; 17′ 0″ and 9′ 0″.

We have thus, doubtless, come upon the explanation of the old Detroit river channel already named: First, a shallow Silurian synclinal dip; then a rock elevation interposed in the path of the glacier, consisting of a low Silurian anticlinal bank, with Transitional and Anderdon rock superimposed, and all of this elevated by a thrusting movement.

CORNIFEROUS AND ANDERDON MATERIAL.

All the Anderdon limestone material seems to have come in from the south, as has been already stated. Because of the greater depth of the deposit within the cul de sac basin as compared with the supplying valley from the south another valley was suspected leading to the eastward from the basin. That side also was thoroughly tested in the hope of finding such a valley. There is a valley—but not of the supposed age. It carries only Corniferous material. That there is a valley of shallow dimensions goes to show a slight letting down of a surrounding anticlinal tongue of Silurian age which has admitted the Corniferous sediment from the eastward, none of which came in by way of the Malden Valley; around the tip of which upward fold of Silurian, and toward the south, the Anderdon has circled about, with normal depth, to cross Detroit river in the neighborhood of the upper end of Grosse Isle where there is a showing of Corniferous at the surface, to be again quarried, in its normal depth, in the bottom of the Sibley quarry, almost opposite the phenomenal depth in the Amherstburg quarry.

A cross section of the whole Detroit river area between these two quarries would show nothing of the Anderdon beds from shore to shore

*Test holes "1," "9," "7," 19 and 20.
†Test holes 10, 11, 12, 13, and the Borrowman well.
‡Test holes Nos. 26 and "1"; Nos. 5 and 29.

of the river. Much less would such cross section show the Detroit river bottom bed of dolomite to overlay Anderdon limestone—to which river bottom strata Grabau and Sherzer have given the name of Amherstburg Dolomite. Neither will it show Sylvania Sandrock at the base of Flat Rock dolomite over this area. Nor are the strata of the Detroit river series of Upper Monroe age, except in the upper reaches of the river; and except as the Upper Monroe strata round the head of the extreme northerly limit of the Cincinnati anticline and circle back to south'ard. On the contrary, and with the exception noted, the characteristics of these strata are those of the Lower Monroe. Compared with the Ballville section of the Ohio Greenfield dolomite this rock also is* "a light-colored dolomitic calcilutite." Like the Lower Monroe beds of Maryland these beds also are †"nearly all calcilutites, mostly thin-bedded, well stratified." As in the case of the Raisin River dolomite, at a given horizon *"hemispherical masses protrude . . . having a finely laminated, concentric structure and apparently concretionary in their structure;" and, "locally the beds contain patches of iron pyrite." The upper beds are almost fossil-free, which will not be said to be a characteristic of the Upper Monroe strata. And, in addition, the sharp directly southward dip of the strata in all the central part at least of the area in question is in itself a statement of the fact that here is the rock against which the Upper Monroe banks, stratum upon stratum, with dip swinging from westward to northward in Monroe and Wayne counties.

One further remark about the age of the Anderdon limestone beds. Professor Grabau has emphasized their Devonic affinities. I have shown that these beds do not sandwich between two dolomities; that they rest upon a dolomitic limestone transitional in character and Devonic in its chief characteristics; and that they are Devonic in chemical properties, analyzing in some instances 99.55 $CaCO_3$. And, whereas †Grabau describes "the Monroe beds and underlying formations (as) all involved in slight folding *which took place in post-Monroe and pre-Dundee times*," I have shown the Anderdon limestone beds occupying the synclinal space between two of these lateral folds.

Altogether it would appear that the Anderdon Limestone beds have been wrongly classed as Siluric; in short that they are of Devonic age.

Amherstburg, Ontario, March 28th, 1911.

*Stratigraphy, Structure and Local Distribution of the Monroe Formation; by Professors W. H. Sherzer and A. W. Grabau.

† "Correlation of the Monroe Formation of Michigan, Ohio and Canada with the Upper Siluric of Eastern North America and elsewhere," Mich. Geolog. Survey, 1909. The Monroe Formation.

THE SPERMATOGENESIS OF AN ORTHOPTERON, CEUTHOPHILUS LATEBRICOLA SCUDDER, WITH SPECIAL REFERENCE TO THE ACCESSORY CHROMOSOME.

CRYSTAL THOMPSON.

CONTENTS.

I. INTRODUCTION.

Many studies have been made of Orthopteron spermatogenesis with reference to the accessory chromosome. The results embodied in this paper, though they do not add many new facts to those already observed, bring into line one more species and put forth additional proof of the presence of an accessory chromosome. This chromosome has been traced from the spermatogonia to a rather late stage in the transformation of the spermatid. For a discussion of the literature on insect spermatogenesis in general, and the spermatogenesis of the Orthoptera in particular, the reader is referred to Davis (1908).

The work here reported was begun at the Marine Biological Laboratory[1], Woods Hole, Mass., during the summer of 1909, under the direction of Prof. T. H. Montgomery, Jr., and was carried on during the winter of 1909-1910 at the University of Michigan, under the direction of Dr. R. W. Hegner. I wish to thank both Prof. Montgomery and Dr. Hegner for their helpful suggestions and the interest they have taken in the work.

[1]The author wishes to thank Mr. Bryant Walker and the Zoological Department of the University of Michigan for the opportunity of occupying a table at the Marine Biological Laboratory during the summer of 1909.

EXPLANATION OF FIGURES.

All figures with the exception of Fig. 1 were made with the aid of a camera lucida. Fig. 1 is a freehand drawing x7.

Figure 1. Portion of testis.
Figure 2. Apical cell with surrounding primary spermatogonial cells.
Figure 3. Equatorial plate of secondary spermatogonial nucleus, showing accessory chromosome (x).
Figure 4. Metaphase of secondary spermatogonium, showing accessory chromosome, x.
Figure 5. Late anaphase of secondary spermatogonium, showing limbs of accessory lagging behind.
Figure 6. Early growth period, the accessory at x, the nucleolus at n.
Figure 7. Later growth period.
Figure 8. Late growth period, showing polar arrangement of spireme, and position of accessory, x, and of the nucleolus, n.
Figure 9. Very late growth period, showing splitting of the spireme.
Figure 10. The beginning of tetrad formation. Accessory at x.
Figure 11. Various forms of tetrads.
Figure 12. Metaphase of first maturation division.
Figure 13. Late anaphase of first maturation division, accessory at x.
Figure 14. Anaphase of first maturation division.
Figure 15. Late prophase of first maturation division.
Figure 16. Metaphase of second maturation division, accessory at x.
Figure 17. Late anaphase of second maturation division, without the accessory chromosome.
Figure 18. Telophase of second maturation division, nebenkern at y.
Figure 19. Two spermatids lying side by side, one showing the accessory, the other not. Accessory, x. Nebenkern, y.
Figure 20. Stage in the transformation of the spermatid.
Figure 21. Nearly mature sperm.


1
2
3
x
4
x
5
6
n
x
7
n
x
8
x
n
9
n
x
10
x
11
12
x
13
x
14
x
15
16
x
17
18
y
19
y
y
x
20
21

II. MATERIAL AND METHODS.

Specimens of *Ceuthophilus latebricola* Scudder were collected at Woods Hole during the summer of 1909. This species was found living under pieces of bark, paper and similar objects in wooded places. Many specimens were also found living under and around the decaying curbing of an old well.

The method of preparing the material was as follows: The testes were dissected out in salt solution and immediately fixed, some of them in Flemming's strong chromo-aceto-osmic fluid and some in Carnoy's fluid. Flemming's fluid gave the best results. After fixation the testes were hardened for a few days in alcohol and then embedded in paraffin. Sections were cut six and nine micra thick. Several staining methods were used but Heidenhain's iron-hemotoxylin, counterstained with orange G, eosin or Bordeaux red gave the best results. Flemming's triple stain also proved of value.

III. OBSERVATIONS.

STRUCTURE OF THE TESTES.

The testes of *Ceuthophilus latebricola* Scudder occur as paired organs lying one on either side of the dorsal abdominal wall. They are composed of a number of follicles arranged in parallel series along the vas deferens. (Fig. 1.) In young individuals the follicles are globular in form but in the older insects they become elongate. A short tube connects each follicle at its proximal end with the vas deferens.

Longitudinal sections of the follicle show near the distal end a large apical cell. This cell can be distinguished from surrounding cells by its greater size and different staining reaction. The apical cell is surrounded by primary spermatogonia, which are arranged in a radiating row (Fig. 2). The nuclei of the spermatogonia are eccentrically placed, being nearest the side away from the apical cell. The chromatin is scattered through the nuclei in the form of fine granules.

The secondary spermatogonial cells are arranged in cysts or groups of cells; each cyst enclosed in a thin membrane. These cysts persist throughout the development of the germ cells, the cells in one cyst being all in approximately the same stage of development. An exception to this occurs in the case of the primary and secondary spermatocytes. Secondary spermatocytes are sometimes found in the same cyst with primary spermatocytes. There is a more or less regular succession of cysts arranged in the follicle from the distal to the proximal end. The older cysts gradually approach the proximal end of the follicle and the younger ones develop at the distal end. The cysts at the distal end are small, two, three or more occupying the diameter of the follicle, whereas in the later stages a cross section often shows one cyst occupying this entire space.

Follicles taken from young individuals in May, 1910, were filled with cysts of spermatogonial and spermatocyte stages, whereas material taken in late July and August, 1909, had the proximal two-thirds or more filled with spermatids and mature sperm. It seems probable from

these observations that the breeding season for this species extends over a period from about the first of August to the first of September. This is further strengthened by the examination of females which were not ready to lay eggs before the latter part of July and were without eggs in the middle of August.

THE SPERMATOGONIA.

As stated above there is in each follicle an apical cell around which are grouped the primary spermatogonial cells (Fig. 2). The nucleus of the apical cell is large and the chromatin is scattered through it in the form of fine granules. There may be one or more plasmosomes present.

The nuclei of the primary spermatogonial cells are larger than those of the secondary spermatogonia. The chromatin contained within them consists of widely scattered granules. The nuclei are eccentrically placed; most of the cytoplasm, which is relatively large in amount at this stage, being on the side nearest the apical cell.

In the actively dividing secondary spermatogonia the chromosomes, when in the equatorial plate, appear as more or less curved rods (Fig. 3). They are rather evenly distributed about the plate with the largest at the periphery. The chromosomes vary considerably and it is possible to select pairs of them of approximately the same size and shape. This, however, cannot be done with certainty for all of them. There is a large horseshoe shaped chromosome (Fig. 3x) which always lies at the edge of the plate, and for which there is no mate; this is the accessory chromosome.

The autosomes split longitudinally in the spermatogonial divisions. The accessory chromosome also splits longitudinally, and in favorable sections it can be seen in metaphase, projecting slightly from the plate (Fig. 4x). It lags behind the rest, one-half passing to either pole of the spindle. The two long arms can be seen stretching toward each other after the autosomes have reached the poles (Fig. 5).

The chromosomes are so closely packed in the spermatogonial plates that they can seldom be counted with accuracy. Furthermore there are relatively few spermatogonial nuclei in the proper stage for the determination of the number of chromosomes. Because of these two facts the number could not be determined with certainty but there are probably thirty-seven or thirty-nine in the spermatogonia.

GROWTH PERIOD OF THE PRIMARY SPERMATOCYTES.

During the telophase of the last spermatogonial division there is a diffusion of the chromatin within the nucleus. At the earliest stage there is no spireme, the chromatin being scattered throughout the nucleus in the form of fine granules (Fig. 6). A spireme then appears with the chromatin granules distributed evenly upon it. At the intersections of the thread the granules appear somewhat condensed. The spireme at this time has no definite position (Fig. 7); soon, however, it assumes the usual polar arrangement (Fig. 8). The thread or threads are apparently fastened to one side of the nuclear wall, and the loops extend out into the nucleus from this place of attachment. The loops are fastened to the distal pole of the nucleus, as determined by the position of the greater part of the cytoplasm. It was not possible to count the loops of the

thread because of the many convolutions and their crowded condition in the nucleus. They are doubtless fewer in number than the autosomes in the spermatogonia, probably only one-half as many being present. It would appear from this that each loop represents two equivalent autosomes of the spermatogonia.

At a somewhat later stage the single spireme thread shows a double structure (Fig. 9) due to the splitting of the thread. This splitting has never been actually observed but the thread is distinctly double in places in the late growth stages. Each granule of one thread is opposite a similar granule of the other thread, making it appear as though each thread were made up of halves of the granules of a single spireme. The splitting is not distinct throughout any great length of the thread at one time, due to the convolutions of the thread and to the small size of the chromatin granules. No evidence of a side to side union of the spireme threads as described by Otte (1906) for Locusta was observed. Only a few cases were observed in which there was even an apparent side to side union of the threads, and these seem to be in all cases accidental; two threads may lie side by side for some little distance but always diverge if followed far enough. The fact that there is a polar arrangement of the loops would necessitate the parallel position of some of them. It could not be determined whether the spireme was a continuous thread or was segmented. The complex course of the thread and the large amount of chromatin contained in it make it impossible to trace, with certainty, for any distance.

At no time was there a massing of the loops at one side of the nucleus. Since there has been so much discussion and disagreement on the part of investigators concerning this point, it might be interesting to add that, in none of the properly fixed material did such a stage occur; however, in one slide prepared from a poorly fixed testis, this stage was very conspicuous, in fact, a large number of the nuclei which were in growth stages showed this condition. From these two facts it would seem that in *Ceuthophilus latebricola* at least, there is no synizesis stage.

During the growth period the accessory chromosome appears as a deeply staining oval body against the nucler wall. It can be distinguished from the nucleolus throughout the growth period by its position and its oval form. In every case the accessory chromosome lies against the nuclear wall, whereas the nucleous may take up any position within the nucleus (Figs 6, 7, 8, 9).

TETRAD FORMATION: DIVISION OF THE PRIMARY SPERMATOCYTES.

At the close of the growth period the loops of the spireme begin to break up and become situated around the periphery of the nucleus. The early tetrad formative stages show the spireme broken up into segments of unequal length. When the thread begins to segment in this way it is possible to recognize the quadripartite nature of the future chromosomes (Fig. 10). Some of the broken segments may stretch entirely across the nucleus, whereas others are not more than one-fourth of this length. As development goes on the segments gradually condense but still retain the characteristic form. Throughout the entire period of tetrad formation it is possible to trace the general shape and quadripartite character of the chromosomes.

The tetrads show a variety of forms which may be grouped as rods, crosses and rings. Some of them are straight double rods with a slight opening in the center; others are so bent upon themselves as to appear y shaped; and still others are so curved as to resemble a twisted doughnut. The most common form assumed is that of a ring. Sections well destained show very clearly the quadripartite structure of the rings. Figures 10 and 11 show some of the characteristic form of the tetrads.

During the formation of the tetrads there can be distinguished in the nucleus a deeply staining, compact body, the accessory chromosome (Fig. 10). In preparations which have been destained for some time the ordinary chromosomes present a rough, granular appearance but the accessory remains compact.

At the time when the tetrads take on a homogeneous appearance, the nuclear wall breaks down and the chromosomes pass into the late prophase of the first spermatocyte division (Fig. 15). The primary spermatocyte division is relatively short as compared with the growth period, but, on the other hand, it is relatively long when compared with the secondary spermatocyte division. At least one is lead to conclude this from the fact that a large part of the follicle is composed of cells which are in the growth period. Most of the actively dividing cells are primary spermatocytes and it frequently happens that considerable search is necessary in order to find secondary spermatocytes. The secondary spermatocytes can be distinguished by the characteristics of the mitotic figure. The chromosomes are smaller and appear in metaphase as dumb-bell forms on the spindle (Fig. 16).

When the autosomes of the primary spermatocytes take up their position in the equatorial plate the accessory chromosome moves toward one pole of the spindle. It may occupy various positions, either directly at the pole, at some place between the pole and the equator, or entirely outside the spindle as described by Baumgartner (1904) for Gryllus. Some of the various positions it takes up are shown in Figs. 12, 13, 14. The accessory is bean-shaped and shows a more or less distinct longitudinal splitting (Fig. 12). The concave side may be toward or away from the spindle. It does not divide in the first spermatocyte division. Occasionally this chromosome lags behind the others and appears as a large distinct element on the spindle after the other chromosomes have reached the poles (Fig. 13). It is a striking fact that cells which exhibit this peculiarity occur in groups, and are not scattered among the other types of cells. Up to the present time a large enough number of these cells have not been found to warrant separating them as a distinct type.

In the metaphase the autosomes take up a position along the equatorial plate so that the long axis is at right angles to the spindle axis. As the mantle fibres contract the chromosomes are pulled apart and pass to the poles as loops (Fig. 14). The middle of each segment separates from its fellow first but the ends remain in contact for some time, the pull of the mantle fibres stretching out the two chromosomes in a plane at right angles to the original axis, thus giving, at first glance, the appearance of a transverse division at this stage. However, careful tracing of the chromosomes from the tetrads to the anaphase indicates that the first division is longitudinal.

DIVISION OF THE SECONDARY SPERMATOCYTES.

The chromosomes of the secondary spermatocytes are smaller and more compact than those of the first. Most of the nuclei examined had their chromosomes in the equatorial plate. The chromosomes appear as small blocks (Fig. 16), presenting a very different appearance from those of the primary spermatocytes (Fig. 12). In a part of the nuclei the accessory chromosome appears projecting out from one side of the plate (Fig. 16). It is of course considerably larger than the other chromosomes. It divides with the rest and its chromatids pass with the others to the poles of the spindle. Since the accessory is larger and longer than the autosomes its ends project down towards the equator of the spindle after the ordinary chromosomes have reached the poles. The division of the nuclei which do not contain an accessory is in all other respects similar to those which do.

The result of the first spermatocyte division is the production of two secondary spermatocytes, one with an accessory chromosome and the other without. The secondary spermatocytes divide, the one without the accessory giving rise to two spermatids, neither of which contains an accessory chromosome; the other, with the accessory, giving rise to two spermatids each of which contains one of the chromatids of the accessory. Thus a single primary spermatocyte gives rise to four spermatids, two of which contain an accessory chromosome and two of which do not.

TRANSFORMATION OF THE SPERMATIDS.

The chromosomes rapidly break down after the last spermatocyte division. At first they congregate in the nucleus in the form of a loose crescent and then become granular (Figs. 18, 19). There are small aggregations of granules around the nuclear membrane in many cases but these are not pronounced (Fig. 19). In the spermatids containing the accessory chromosome this chromosome can be recognized as a compact deeply staining oval body closely applied to the nuclear membrane (Fig. 19). It has much the same appearance that it had in the growth stages but it is of course smaller. Frequently two spermatids were found lying side by side, one with the accessory chromosome, the other without (Fig. 19).

During transformation the spermatid gradually assumes a spindle shape and a tail is formed (Figs. 20, 21). At this time there is no apparent difference between spermatids with the accessory chromosome and those without.

There appears in the cytoplasm of the cells in the growth period a rounded or oval body which stains more deeply than the rest of the cytoplasm. This body can be traced throughout the growth period and also through the late spermatocyte stages and spermatid transformation. It is small during the growth but becomes a very large and conspicuous element in the spermatids. It is probably the Nebenkern (Figs. 13, 19).

IV. DISCUSSION.

The apical cell is such a large and imposing element in the follicle that it should not be overlooked. This seems to have been generally done by writers on Orthopteron spermatogensis. Davis (1908) however dis-

cusses it quite in detail. This cell in Ceuthophilus agrees in general with the description given by him for the Acridiidae and Locustidae.

The more or less definite pairing of the autosomes in the spermatogonia is in accord with the results of most other writers and seems to point to the fact that there is a double series of chromosomes, of approximately equal form and volume, one paternal, and the other maternal.

Ceuthophilus apparently agrees with most other Orthoptera in having an end to end union of the chromosomes in synapsis and later, in the formation of the tetrads, by a splitting of the spireme thread. From the observations made the first maturation division is probably longitudinal and the second transverse. However, this could not be determined with certainty so it is useless to discuss its relation with other forms in this respect.

Ceuthophilus agrees with other Orthoptera in having an accessory chromosome which in the spermatogonia is larger than the autosomes. It remains compact throughout the growth period and tetrad formation stages, dividing in the secondary maturation division but not in the first. It can be traced with ease from the spermatogonia to a rather late spermatid stage.

V. SUMMARY.

There is near the distal end of each testicular follicle an apical cell surrounded by primary spermatogonial cells. The secondary spermatogonia are enclosed in cysts of connective tissue cells. The spermatogonial chromosomes divide longitudinally, the accessory chromosomes with the rest. During the growth period the autosomes become diffuse whereas the accessory remains a compact body applied to the nuclear membrane. The spireme assumes a polar arrangement in the middle and late growth periods, and splits longitudinally at the beginning of tetrad formation. During the period of tetrad formation the accessory remains compact. The first maturation division is probably longitudinal, the second transverse. The accessory chromosome divides in the second maturation division and not in the first, one-half of the sperms therefore contain an accessory chromosome and the other half do not.

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Ann Arbor, Mich., April, 1911.

NOTES ON THE AMPHIBIANS AND REPTILES OF CASS COUNTY, MICHIGAN.

CRYSTAL THOMPSON.

The data set forth in this paper are the result of an expedition sent by the University of Michigan Museum to Cass County, Michigan, during the summer of 1910. The party was composed of Miss Frances Dunbar and the writer. The field work extended from July 14 to July 30, inclusive, and was supplemented by a week's work by the writer in May, 1911. The investigations were undertaken as a part of the general biological survey of the state that is being carried on by the Museum and the Michigan Geological and Biological Survey.

Cass County lies in the southwestern part of the lower peninsula of Michigan. It is one of the lower tier of counties and is separated from Lake Michigan by but one county, Berrien. Its importance biologically is due to the proximity of the prairie region to the south and west and to the fact that it is one of the few counties in Michigan which lies in the Upper Austral faunal zone of Merriam. One might very well expect then, to find any prairie forms from Indiana and Illinois that extend into the state and the most southern species in the Michigan fauna. The topography of the county is characteristically that of a glaciated region. The land is for the most part gently rolling with a few small areas of more level prairies. There is an abundance of small lakes; these lakes covering approximately twenty square miles. Christiann Creek in the southeast portion and Dowagiac Creek in the northwest portion with their smaller tributaries serve to carry the drainage into the St. Joseph River.

The work of the expedition was carried on in the central part of the county, about Diamond Lake and the group of lakes known as the Mud Lakes of Jefferson and Calvin townships. These regions were selected because of the fact that they furnished a variety of surface features, and also because it was known that the region was rich in amphibians and reptiles.

Diamond Lake is situated about one-half mile from the village of Cassopolis. It is about two and one-half miles long by one mile wide, with an island of about eighty acres in the center. The banks rise gently from the waters edge and are covered in places by dense beech and maple forests, or by cleared fields. At the southeast end is Turtle Bay, a small, rather deep bay, the bottom of which, in contrast to the sandy bottom of the rest of the lake, is muck. The banks, instead of rising from the water as gentle slopes, are mere swamps of rushes and willows.

The chain of three lakes, known as the Mud Lakes, is situated about two miles south of Diamond Lake, and is also drained by tributaries of Christiann Creek. They cover an area approximately one and one-fourth miles long by one-fourth mile broad, and are, as the name implies, mud bottom lakes, with deposits of marl in some places. The banks are swampy and there is a dense growth of water plants over the bottom. The upper and longer lake of the chain is known as Long Lake, another below this, and into which a ditch empties is called Ditch Lake, and the

third, which is the outlet for the other two, is commonly known as Parker Lake.

Collecting was carried on principally about Diamond and Mud Lakes, but one trip was also made to Goose Lake, which lies about three miles west of the Mud Lakes and is drained by a ditch which empties into Ditch Lake. Special attention was given to the amphibian and reptilian fauna although other forms were also collected. The Mud Lakes were especially rich in both these groups as was to be expected from the character of the lakes themselves and from the surrounding country. Diamond Lake was not rich in either amphibians or reptiles except in Turtle Bay. We found several species of turtles there but were particularly impressed by the large number and the size of the soft shells.

It may be worth while to mention that we had the best of success in capturing turtles by using a turtle net with a two-inch mesh. Set in a favorable situation this net would capture as many as twenty specimens in one day.

Two hundred and twenty-nine specimens representing eight species of amphibians, six species of snakes and seven species of turtles were obtained. This gives a fairly good knowledge of the fauna of the region, although there are of course, a number of other species there that were not found. The forms not represented in the collection must, however, be rare.

LIST OF SPECIES.

AMPHIBIA.

1. *Bufo americanus* Le Conte.—Several young specimens and two adults were taken. This species is very common in the region.

2. *Hyla pickeringii* Holbrook.—Two specimens were taken in a swampy place near Long Lake.

2a. *Hyla versicolor* Le Conte.—Two specimens were taken May 21, 1911. The species is common in the region.

3. *Rana pipiens* Shreber.—This species was seen frequently along the shores of the lakes and in the high grass. Sixteen specimens were taken.

4. *Rana clamitans* Latreille.—The green frog was very common. It was especially abundant in and near a small stream which forms the outlet for a spring near the boat landing on Long Lake. Twelve specimens were taken.

5. *Rana catesbiana* Shaw.—One specimen was taken at Long Lake. They are found there in considerable numbers, and also at Goose Lake.

5a. *Rana palustris* Le Conte.—This species was found in large numbers along the ditch about one-half mile from Ditch Lake, and also on the shore of Long Lake. Forty-eight specimens were taken in May, 1911.

5b. *Acris gryllus* Le Conte.—A single specimen was taken May 22 but later escaped.

SERPENTES.

6. *Thamnophis sirtalis* (Linneaus).—This species was found along the borders of marshes and lakes and was usually taken in early evening. Two specimens were taken from a hollow tree on the edge of a marsh. Ten specimens were taken.

7. *Natrix sipedon* (Linneaus).—Two specimens of this watersnake were taken, one from the water on Diamond Lake and the other from

Fig. 1 Trionyx spiniferus (Le Seur)

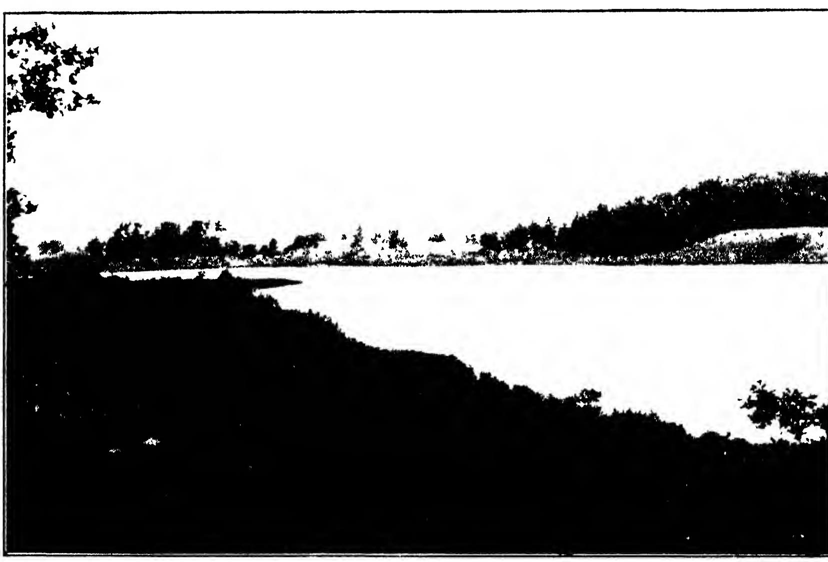

Fig. 2. Long Lake

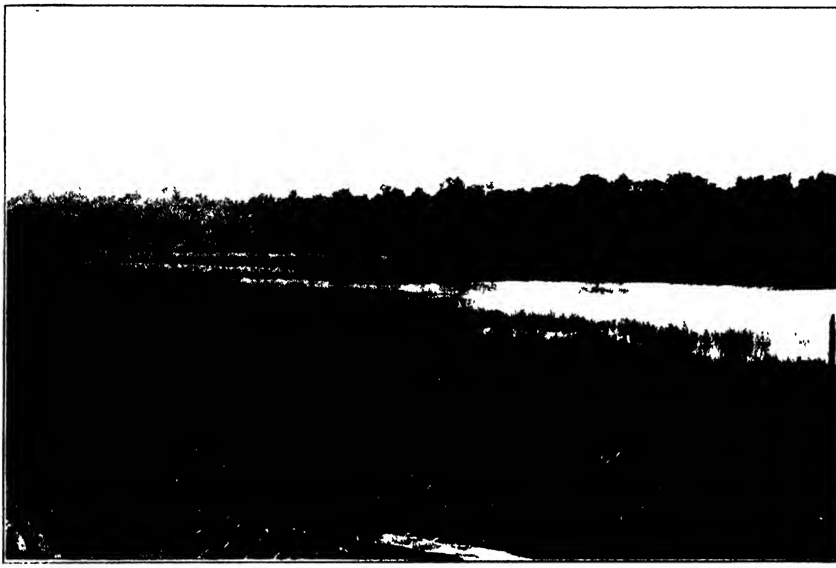

Fig. 3. Turtle Bay, Diamond Lake.

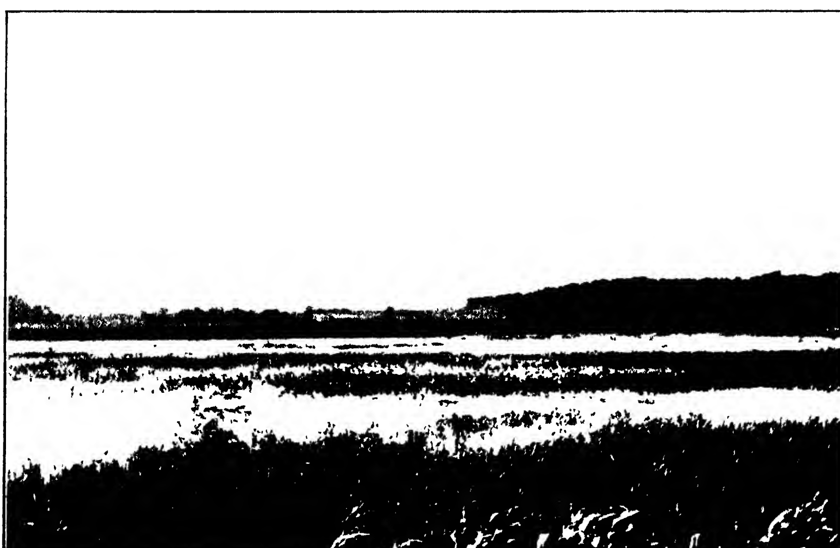

Fig. 4. Goose Lake.

the bank of a small ditch near Ditch Lake. It was common along the borders of the lakes and streams.

7a. *Bascanion constrictor* Linneaus.—This species occurs commonly along the borders of marshes and lakes. Four specimens were taken in May, 1911.

7b. *Ophibolus doliatus triangulus* (Boié).—A single specimen was taken in May, 1911.

8. *Heterodon platyrhinus* Latreille.—One specimen was taken in Cassopolis and later presented to us. Inasmuch as the residents generally confuse those snakes which even in a slight respect resemble the rattler, it was impossible to get other certain records of its occurrence in the region. It is to be expected that it occasionally comes in from the sand region along the shore of Lake Michigan.

9. *Sistrurus catenatus* (Rafinesque).—Two rattlesnakes were taken. One, a large female was found under a pile of old stumps at the border of a marsh; the other, a very small individual, was discovered coiled up on a tuft of grass at the boat landing on Long Lake.

TESTUDINATA.*

10. *Trionyx spiniferus* Le Seur.—Three soft-shelled turtles were secured, one from Long Lake and two from Turtle Bay, Diamond Lake. It was very plentiful in Turtle Bay, but only one other than the one taken was observed in Long Lake, and it probably occurred in smaller numbers there.

11. *Chelydra serpentina* Linneaus.—This species was very common throughout the region. That it is a very favorable locality for them is also shown by the very large size to which they attain. Twelve specimens were taken.

12. *Aromochelys odoratus* Latreille.—This species was abundant in the Mud Lakes, but none were seen in Diamond Lake. Nine specimens were taken.

13. *Chrysemys cinerea* (Bonn).—This species was found in large numbers in all the lakes worked, and frequently on land. Sixty-four specimens were secured. Many of these showed marked variation in the number and arrangement of the plates of the plastron.

14. *Emys blandingii* (Holbrook).—Three specimens taken in Mud Lake, together with another which escaped were the only individuals of this species seen.

15. *Clemmys guttata* (Schneider).—But one specimen of the spotted turtle was taken in 1910 and no others were seen. The specimen secured was caught in the turtle net set in a ditch where they were formerly very abundant. There is a specimen in the University of Michigan Museum which was taken from the same place in 1907. Eighteen specimens were secured in 1911.

16. *Terrapene carolina* (Linneaus).—The land tortoise is quite common in the region, especially in the woods on the high banks along Ditch Lake. Three specimens were taken, two near the lake and the third in the woods along the ditch about a mile from the lakes.

Ann Arbor, Mich., April, 1911.

* *Malaclemys geographica* (Le Seur).—Probably occurs in Cass County, since Gibbs, Notestein and Clark (Annual Report Mich. Acad. Sci., 1905, p. 110) list it from Van Buren County, and there are specimens in the University of Michigan Museum from St. Joseph County.

REPORT ON THE CRUSTACEA COLLECTED BY THE UNIVERSITY OF MICHIGAN-WALKER EXPEDITION IN THE STATE OF VERA CRUZ, MEXICO.[1]

The University of Michigan-Walker Expedition (summer of 1910), under the direction of Dr. A. G. Ruthven, obtained representatives of eleven species of crustaceans, four of them new, in southern Vera Cruz. The following paper is the result of the study of this material and contains the descriptions of the new species.

Most of the specimens were collected on the hacienda of Cuatotolapam which is on the plain at the base of the San Andreas Tuxtla mountains and in the canton of Acayucan (elevation fifteen meters). Several species were taken at Lake Catemaco, at an elevation of 398 meters, in the San Andreas Tuxtla range.

The numbers given to the specimens refer to the University of Michigan Museum catalogs.

COPEPODA.

1. *Cyclops leuckarti* Claus.—Six individuals of the species were collected with a Birge net from La Laja creek at Cuatotolapam on August 8, 1910.

OSTRACODA.

2. *Cypridopsis* sp.—Several specimens thus identified by Prof. Sharpe were taken in the shallow water in Lake Catemaco on July 27.

ISOPODA.

3. *Cubaris walkeri*, new species.—Body convex, minutely granulate; thoracic segments each with an elongated swollen mass of blended tubercles on each side 1 mm. from the middle line. Head more than twice as wide as long; anterior margin straight, strongly reflexed; eyes rather large, sixteen ocelli. Antennae with flagellum shorter than last joint of peduncle; first joint of flagellum less than a third as long as second. First segment of body separated by grooves from the lateral margins which are somewhat reflexed; lateral margins of other thoracic segments narrow, strongly flexed posteriorly; first coxipodite free along whole outer margin, divergent at posterior end; second coxipodite free along outer end and anterior margins, divergent at outer edge. Pleotelson strongly constricted in the middle, about as wide as long, width at distal end one-fourth less than at proximal end; a low tubercle near

[1]When Dr. Pearse was called to the University of the Philippines, in April, 1911, this paper was completed except for the identifications of the ostracods and shrimps, and two species of Isopoda. He had already submitted the ostracod material to Prof. R. W. Sharpe for identification, and the other undetermined specimens were later sent to Miss Mary J. Rathbun of the U. S. National Museum. A specimen of *Probopyrus bithynis* found by Miss Rathbun on one of the shrimps and another species of isopod (*Porcellio rathkei*) that had not been submitted to Dr. Pearse were identified by Dr. Harriet Richardson. The Museum is indebted to these persons for their assistance.

A general account of this expedition will be published in the annual report of the head curator of the University of Michigan Museum for the year 1910-1911.—*Alexander G. Ruthven.*

proximal margin in median line. Uropoda with basal segment a little longer than wide; inner branch robust, spatulate, more than half as long as pleotelson, attached on the posterior inner margin of basal segment; outer branch small, conical, inserted more on the dorsal than ventral surface of the basal segment at the middle of its inner margin. Color of alcoholic specimens slaty; a series of longitudinal median white blotches along the segments from the head to the pleotelson; lateral margins of first, third, fourth and all abdominal segments more or less white. Dimensions: 11 by 5.5 millimeters.

Eleven specimens of this species (41706, 41709, 41711, 41712, 41713) were collected between August 3 and August 13, 1910. The two type specimens were taken at Cuatotolapam, August 4, and all of the others were secured at the same place. All of the individuals were found under logs, leaves or stones. The species is named for Bryant Walker of Detroit, Michigan, whose generosity made the expedition possible.

4. *Probopyrus bithynis* Richardson.—A specimen of this species was found by Miss Rathbun within the branchial chamber of one of the specimens of *Macrobrachium olfersii*. According to Miss Rathbun this is the first time that the species has been found parasitic on this shrimp.

5. *Porcellio rathkei* Brandt (?).—Several specimens thus identified by Dr. Richardson were taken in decaying palm trees in low jungle at Cuatotolapam. Dr. Richardson states that the markings differ from those shown by individuals from the United States, but that this is probably but a variation exhibited by *P. rathkei*.

AMPHIPODA.

6. *Hyalella ornata*, new species.—Body slightly compressed; pleon segments 1 and 2 each produced into a dorsal spine in large individuals. Head longer than first peraeon segment; eyes large, elongated, elliptical. Side plates 1-4 rectangular with rounded corners. Pleon segments 3, posterior lateral angles slightly produced, tip rounded. Antenna 1 reaching beyond middle of flagellum of antenna 2, flagellum longer than peduncle, 6-7 segmented. Antenna 2 with ultimate segment of peduncle a little longer than the penultimate, flagellum longer than peduncle. Maxilla 1 with four plumose setae on apex of inner plate. Gnathopods ornamented with low, cresentric, hairy tubercles. Gnathopod 1 slender, palm transverse, sinous, defined by a tubercle. Gnathopod 2 in male, sixth joint stout, longer than broad, palm oblique, a notch near the base of the finger and a tubercle at the defining angle; finger stout, curved. Gnathopod 2 in female weak and slender, fifth and sixth joints both swollen into a large tubercle on the posterior margin, sixth about twice as long as broad, posterior margin longer than front; palm nearly straight, a shallow notch at base of finger. Posterior margin of second joints of peraepods 2-4 smooth, posterior margin of 5 serrate. Peraepod 4 not quite as long as 5. Ramus of uropod 3 as long as peduncle, slender, tapering, with a tooth and two setae at apex. Telson about as wide as long; apical margin thin and rounded, a slender setae on each side of apex. Length, 4 mm.

This species is given the name *ornata* on account of the tubercles which cover parts of the anterior margins of the last two segments and the

posterior margins of the last four segments of the first gnathopods of both sexes; they are also found on the same places on the second gnathopods of the female, but appear only on the posterior margins of the fourth and sixth segments of the second gnathopods of the male. About 200 specimens were collected in Lake Catemaco on July 27. They were found in large numbers on the stones near shore.

DECOPODA.

7. *Cambarus pilosimanus* Ortmann.—An adult female (41707) of this species was taken from a drainage ditch leading into La Laja creek at Cuatotolapam on July 18. Its measurements are as follows: length of carapace, 37; tip of rostrum to cervical groove, 24; width of carapace, 17; height of carapace, 15.6.

Three young female crayfishes (48708, 41710), about 22 mm. in length, collected on the shore of Lake Catemaco, July 27, appear to belong to this species.

8. *Cambarus ruthveni,* new species.—Only two specimens were collected, a male (41705) and a female (41704). Both were taken as they walked along the bank of a ditch in a guarda raya at Cuatotolapam, July 25. The female was carrying young that had completed their second moult; the male is first form. The characteristics of these two specimens are as follows:

Male: Rostrum subplane, margins elevated, convergent, slightly convex; acumen short, hairy below along lateral margins. Postorbital ridges slightly converging anteriorly, swollen at posterior end. Carapace compressed, plane above, granulated on sides, thickly punctuate above, almost smooth behind rostrum; cervical groove sinuate; no lateral spines; branchiostegal spine very small, blunt; areola almost obliterated in its middle third; posterior triangular space not clearly defined. Abdomen narrow, about as long as carapace; basal segment of telson with three spines on each side. Epistoma with anterior part triangular, rounded at tip. Antennal scale broadest toward the distal end; flagellum reaching to fourth abdominal segment. First pereiopods elongated, hand elongated, somewhat compressed, margins subparallel; surface thickly granulate, granules distinct everywhere but more prominent toward inner margin; fingers almost as long as palm, both with a smooth ridge down the middle of each side, bearing a few tufts of bristles at tip, both denticulate on inner margin, the fixed finger with a larger tooth near base. Carpopodite with a very shallow sulcus on upper side; granulated everywhere; granules larger on inner side. Meropodite granulated above and below; smooth on inner and outer surfaces; granules on lower surface arranged in two rows. Ischiopodite of third pair of legs with a slender pointed hook. First pleopods (Fig. 3 A, B) rather short, straight; anterior margin with a shoulder near tips; outer and inner parts in close apposition to their tips; tip on inner part straight; tip of outer part stouter, blunt, bearing a horny spine near tip, flattened on inner face with hairs pinnately arranged on each side. Length, 58.5 mm.; length of carapace, 30; tip of rostrum to cervical groove, 19; breadth of carapace, 14.6; height of carapace, 14.

Female: Similar to male; granulations on carapace less prominent. Annulus ventralis small, (Fig. 3 C) prominent, hemispherical, with a sinous longitudinal fissure; a conical tubercle (C, D) between the bases of the fifth walking legs which is a little larger than the annulus. Length, 51.7 mm.; length of carapace, 26.6; rostrum to cervical groove, 17; breadth of carapace, 13; height of carapace, 12.2.

This species has the spine between the fifth walking legs of the female which Ortmann assigns as a characteristic of the subgenus *Paracambarus*, but it cannot be placed in that group on account of the characteristics of the male (i. e., the presence of hooks on the third walking legs and the absence of horny tips on the branches of the first pleopods) which are like those of his subgenus *Paracambarus*. Nevertheless, as Andrews has demonstrated the presence of a spine on the sternum of the last thoracic segment in two of Ortmann's subgenera other than *Paracambarus*, i. e., in *Procambarus* (in the form of a rounded tubercle) and *Cambarellus*, the writer would assign *C. ruthveni* to the subgenus *Procambarus*.

Dr. Ruthven says that the species is a burrower, and that the burrows are common along the drainage ditches on the low land at Cuatotolapam.

9. *Macrobrachium acanthurus* (Wiegmann).—Several specimens were taken in seines from the Hueyapam River at Cuatotolapam. It was quite abundant along the shores.

10. *Macrobrachium olfersii* (Wiegmann).—Two specimens were taken in the seines with the last species.

11. *Trichodactylus constrictus*, new species.—The following description is from a female (41717) bearing young under her abdomen.

Carapace punctate above; front margin slightly concave, smooth, slightly reflexed. *H*-shaped depression well defined; posterior ends of lateral margins strongly narrowed, posterior seventh of carapace 3/5 as wide as greatest width; three antero-lateral spines, first one some distance behind the orbit; gastric region strongly elevated. Front abruptly deflexed; orbital sinus in front of carapace rather deep. An obtuse spine at the ventral inner angle of the orbit; an elevated ridge on outer and ventral margins of orbit. Maxillipedes: eschium with inner and outer margins about equal in length; merus with inner margin 1/3 as long as outer; exognath almost as long as endognath. Chelipeds: merus with a pointed spine on the inner and one on the outer margin below; also a spinous tubercle at the outer distal angle; carpus indistinctly punctate, a spine on the inner margin; hand rather flattened, punctations faint and tending to cause low transverse ridges, margins subparallel; fingers flattened, a prominent ridge on upper surface of each, gaping very little at base; nine denticles on moveable finger and eight on fixed finger, these are larger toward the distal ends of fingers. Ambulatory legs little compressed except the fifth pair, all sparsely pilose. Abdomen and under surface of body not punctate. Length of abdomen, 16.3mm; width, 14.6. Length of carapace 17.5; width, 19.

The above description was made from a specimen taken at Lake Catemaco, July 27. Dr. Ruthven reports that it was collected with eight other females (No. 41718) along the lake shore under rocks which were not submerged or even washed by the waves. Four of the individuals

taken were carrying eggs and one besides the type bore young. The measurements of eight females collected with the type are as follows:

Carapace	Length	16.6	16.3	18.0	19.5	17.4	18.1	15.0	17.0
	Breadth	18.0	17.7	19.1	21.0	19.5	20.6	15.8	19.0

No males were collected. The species is named *constrictus* on account of the narrowness of the posterior portion of the abdomen.

EXPLANATION OF FIGURES.

Figure 1. *Cubaris walkeri.* A, ventral view of first and second side plates; B, dorsal view of head; C, second antenna; D, first maxilla; E. last two segments of body and uropeds, dorsal view; F, ventral view of pleotelson and left uropod.

Figure 2. *Hyallella ornata.* A, left second gnathopod of male; B, first antenna; C, second antenna; D, telson; E, uropod; F, first maxilla; G, second gnathopod of female; H, first gnathopod of male.

Figure 3. *Cambarus ruthveni.* A, inner surface of first pleopod of male; B, outer surface of first pleopod of male; C, ventral surface of a part of the seventh and eighth thoracic segments of female showing the annulus ventralis and the spine on the ventral surface of eighth thoracic segment of female.

Figure 4. *Trichodactylus constrictus.* Dorsal view of type female and claw of another female. Photograph taken by E. W. Sink.

Ann Arbor, Mich., April, 1911.

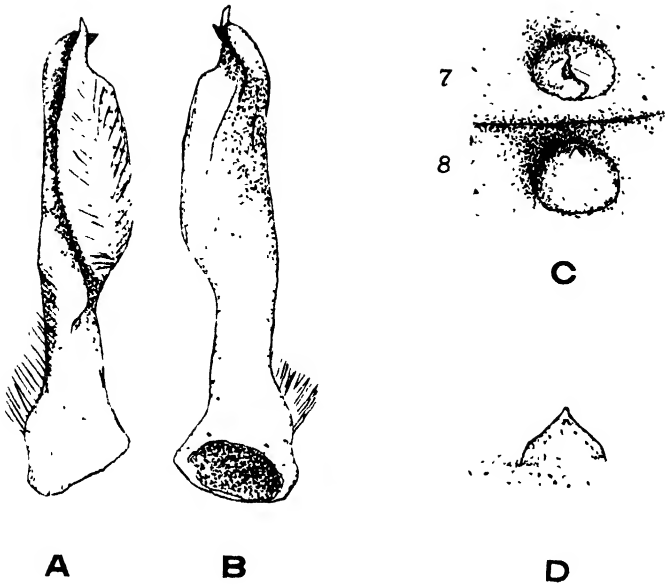

Fig. 3

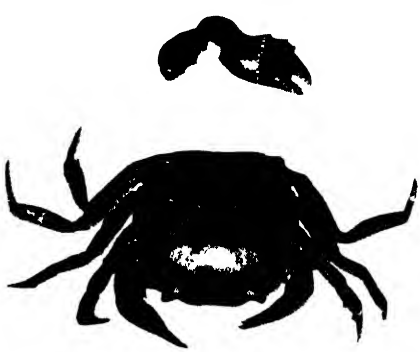

Fig. 4

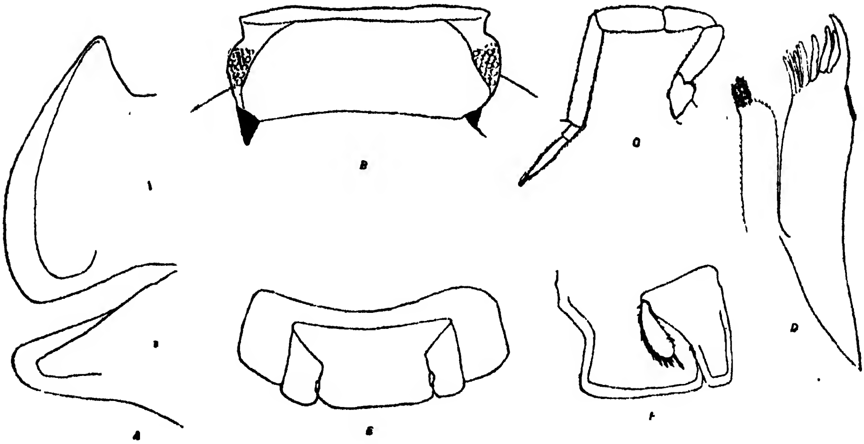

Fig. 1.

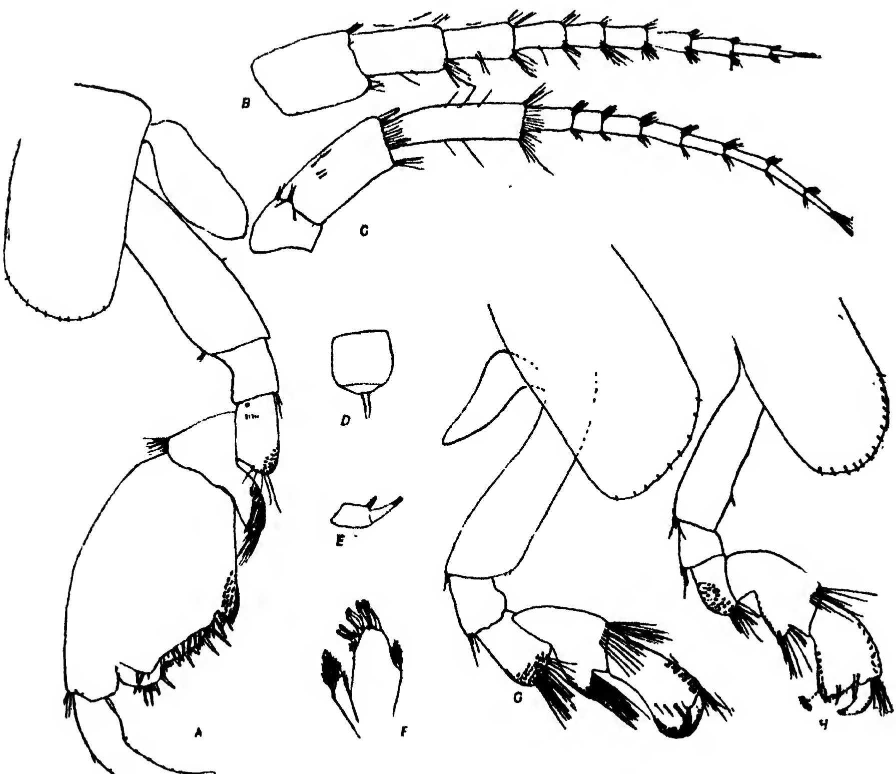

Fig. 2.

NOTES ON MICHIGAN REPTILES AND AMPHIBIANS, III.

ALEXANDER G. RUTHVEN.

A considerable amount of additional data on Michigan reptiles and amphibians has accumulated at the University of Michigan Museum during the past year. Most of it, however, was obtained by the Cass County and Mershon (Charity Island) expeditions, and, as the Cass County material is to be reported upon by Miss Thompson[1] and the data secured by the Mershon expedition is not to be published until after next summer's (1911) work, there remains but little for me to report upon.

Diadophis punctata (Linnaeus).

One of the two most noteworthy additions to the herpetology of Michigan this year was the finding of a specimen of the ring-necked snake at Pine Lake, Oakland County. The specimen was found under the bark of a decaying stump, May 15, 1910, by A. W. Andrews, W. W. Newcomb and P. A. Taverner, and is now, thanks to the kindness of these men. in the museum collection. The scutellation is as follows: dorsal scale rows 15, upper labials 7, lower labials 7, oculars 2-2, temporals 1-1, ventrals 147, subcaudals 57. It is a male and the total length is 378 mm., and the tail length 92 mm.

The ring-necked snake is quite rare in Michigan, and its distribution is very uncertain. The records in the literature are as follows: Michigan[2]; Ann Arbor[3]; Grayling[4]; Eaton County[5]; Olivet, Kalamazoo, and Montcalm and Van Buren Counties;[6] Marquette[7].

The specimen upon which Smith's Ann Arbor record was probably based is in the Museum. It is the only one that I have seen from this locality. Of its occurrence in Eaton County, Clark says: "Rather rare: only two specimens have been examined." One of these (at least one labeled "Olivet") is now in the laboratory of Olivet College[8]. I believe that the Ann Arbor, Olivet (Eaton County), Grayling, and Pine Lake records are the only ones that we can consider reliable at present. The "Michigan" records of Sager and Miles are too general to be of use. The Marquette record was given on the authority of Dr. Downing, and the records for Kalamazoo, Montcalm and Van Buren Counties are unsupported by specimens. Young individuals of *Storeria occipitomaculata* are frequently confused with this species so that one cannot safely rely upon reports.

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[1]13th Ann. Rept. Mich. Acad. Sci..
[2]Sager, A. Senate Doc. State of Mich., 1839, 302. Miles, M. First Biennial Rept. Mich. Geol. Surv., 1861, 233.
[3]Smith, W. H. Supp. Science News, 1879, VII.
[4]Cope, E. D. Rept. U. S. Nat. Mus., 1898, p. 753.
[5]Clark, H. L. Fourth Ann. Rept. Mich. Acad. Sci., p. 193.
[6]Gibbs, M., Notestein, F. N., and Clark, H. L. 7th Ann. Rept. Mich. Acad. Sci., p. 110.
[7]Ruthven, A. G. Rept. Mich. Geol. Surv., 1905, p. 111.
[8]This specimen has been examined for me by Crystal and Helen Thompson. The scutellation is as follows: Dorsals, 15, upper labials 8, lower labials 7, oculars 2-1, temporals 1-1, ventrals 148, subcaudals 50.

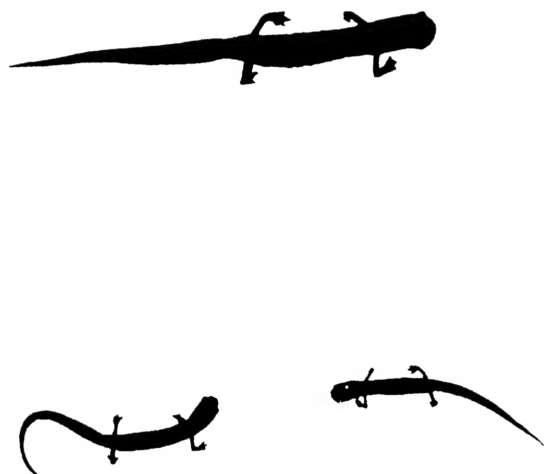

Fig. 1 *Hemidactylium scutatum* (Schlegel) Live specimen Upper figure one and one tenth natural size

Hemidactylium scutatum (Schlegel).

The only Michigan record for this species is Eaton County, as given by Clark[1]. He says: "A single specimen of this uncommon salamander was collected May 13, 1901. It was found in the earth on the roots of a violet, which had been pulled up. So far as I can learn, it has not previously been collected in Michigan. Four other specimens, two males and two females, were taken together in April, 1902, under a log. The females were fully twice as large as the males."

All five of these specimens (at least five specimens) are still at Olivet and have been examined by the Misses Thompson in the preparation of their report upon the amphibians of the state. They have also been so fortunate as to secure an additional specimen from near Ypsilanti. This specimen (Fig. 1) was received alive from Miss Jessie Phelps, and was taken in low wet woods.

THE FAUNA OF THE DOUGLAS LAKE REGION.

The museum has received, from the University of Michigan Biological Station, a considerable amount of material from the vicinity of Douglas Lake in Cheboygan county. No special effort has been made to secure specimens of reptiles and amphibians at the station, so that the collection does not as yet give us an accurate knowledge of the fauna of the region. It is valuable, however, for the additional data on the intrastate distribution of a number of species. The species so far obtained are:

Necturus maculosus Raf.
Plethodon cinereus (Green).
Diemyctilus viridescens Raf.
Ambystoma jeffersonianum (Green).
Rana clamitans Latr.
Rana pipiens Sch.
Rana catesbeana Shaw.
Rana sylvatica cantabrigensis (Baird).
Bufo americanus LeConte.
Natrix sipedon (L.).
Thamnophis sirtalis (L.).
Liopeltis vernalis (DeKay).
Lampropeltis doliatus triangulus (Boie).
Chrysemys cinerea (Bonn.).

Ann Arbor, Mich., April, 1911.

[1]Loc. cit., p. 193.

THE CONCHOLOGICAL SURVEY OF MICHIGAN.

BRYANT WALKER.

The conchological history of Michigan antedates the state itself. The publication by Thomas Say of his celebrated article on "Conchology" in the first American edition of Nicholson's Encyclopedia of Arts and Sciences in 1817 was the real beginning of American Conchology and is the cornerstone of the present elaborate and intricate structure known as our Systematic Conchology.

As early as 1822, by some means not now known, a small lot of shells from Thunder Bay near Alpena came into the possession of Thomas Rackett, then a well-known English conchologist, who published an account of them in the Transactions of the Linnean Society of London of that year. Only seven species are enumerated and to but four of these are specific names given. One, *Helix* (*Polygyra*) *monodon*, still bears the name that he gave it; another had already been described by Say in 1817; the third was the circumboreal *Lymnaea palustris* long before named by Müller and the fourth, *Turbo fontinalis*, has never been identified by any recent author.

It can be said, therefore, with but little fear of contradiction, that the earliest reference to Michigan zoology is to be found in this attempt to exploit its molluscan fauna.

Michigan became a state in 1837. And one of the first acts of the first legislature of the new state was the establishment of a State Geological Survey, with Douglas Houghton at its head as geologist and Dr. Abram Sager as zoologist.

Dr. Sager had already become interested in our local mollusks, and as early as 1836 had supplied Conrad with Michigan material for his "Monograph of the *Unionidæ*." The results of his work in this field were embodied in his report, which bears date, January 12, 1839. It is a simple list, without descriptions or localities, of 75 named species.

The reorganization of the Geological Survey in 1859, brought about the appointment of the late Dr. Manly Miles as state zoologist, who, in 1860, published the second catalogue of Michigan mollusca. This, in addition to a list of 161 species, included a few explanatory notes and descriptions of two supposed new species.

From this time until the establishment of the present Biological Survey in 1905, there was no official recognition of recent conchology by the state authorities. But there was, nevertheless, a steady increase in the knowledge of our fauna through the work of individual collectors. In 1850, A. O. Currier came to Grand Rapids from Troy, N. Y., and in the course of the next thirty years, with the assistance of Dr. W. H. DeCamp, J. A. McNeil and L. H. Streng, made a most thorough exploration of Kent county and did a very considerable amount of collecting elsewhere in the state. The results of their labors were embodied in Currier's catalogue of 1868, which listed 171 species and DeCamp's of 1881, which increased the number to 221 species.

The first regular meeting of this society in December, 1894, was the occasion of the compilation by the writer of a new catalogue, which brought the number of listed species up to 284. A recent list prepared for the present meeting of the Academy recognizes 301 species as represented in our fauna.

The great increase in general knowledge in regard to our mollusca that has accrued during the seventy years that have elapsed since the first catalogue was published by Sager, while adding many new species to our fauna, has also thrown into the synonymy many of the species listed as valid by the early writers, so that the actual increase of our knowledge of the extent of the fauna of the state has been greater than would appear from the face of the returns. Eliminating all doubtful citations and synonyms, the growth of the known fauna of the state during that time is shown by the following summary:

Sager	1839	68 species.
Miles	1860	139 "
Currier	1868	149 "
DeCamp	1881	185 "
Walker	1894	250 "
Walker	1911	301 "

The organization of the Academy in 1894, which has done so much for the advancement of science in the state, had its influence on our local conchology. In 1896 the Conchological Section was organized and through the influence thus exerted, a complete census of all the records of Michigan species contained in all of the public and private collections of the state was compiled and now forms an invaluable record for all future time.

As is necessarily the case in the development of all new territory, the work of the early collectors of the state was collecting, pure and simple, the gathering and identification of material from all possible sources. And it is only of recent years that any attempt has been made to study our fauna as a whole and in connection with the faunas of the adjacent regions, to work out the various problems in distribution that presented themselves. Indeed, it was not possible to take up this phase of the work, until a sufficient amount of collecting had been done in all parts of the state to give a reasonably accurate knowledge of the extent of the fauna and the approximate range of, at least, the leading genera and species. Bricks cannot be made without straw and generalizing on insufficient data is always dangerous business. To these early collectors, then, is to be given the credit of laying the foundations of that detailed knowledge of our fauna that enables us of the present generation, with our greater knowledge of faunal relations, to build our theories of distribution. And, if their light was small, they did their work well according to the light they had and we are now reaping the fruits of their labors.

The establishment of the Biological Survey in 1905, after many years of strenuous endeavor on the part of the Academy, has resulted in large and rapid advances in our knowledge of the fauna of the state and of the distribution of many of the species.

The completion of the survey of Isle Royale, the exploration of the practically unknown district of Huron county, the work in the Menom-

inee region and the expedition of last year to the Charity Islands have all contributed valuable data that we would not have except for the Survey.

The work of the Survey, thus far, has been and must, necessarily, continue to be field work, directed with a special view to collecting data bearing on the various problems involved in the study of the distribution of our fauna. Systematic and continuous field work can only be done under the direction of the Survey. And that must be primarily the work of the Survey. There is no difficulty in getting competent assistance in "working up" all the material that may be collected. The difficulty is in getting the requisite material. And this it should be the duty of the Survey to provide.

Take the subject, in which I am specially interested, for example. We know that our unione fauna is made up of two distinct elements. One, essentially boreal in its character, came in from the north and east. The other from the south and west. Many of the species came from faunal areas that are now wholly separated from the St. Lawrence Basin, in which Michigan lies. The question as to how these species were able to effect a lodgment in our territory is one of great interest and of considerable scientific importance. But, before we can adequately undertake to consider that problem, it is absolutely essential that we should know the exact range in the different drainage areas of the state of the various species involved, and, if possible, the causes that in the past and now seem to limit their range. And it is in just these essential particulars that our present knowledge is deficient. Thus, in the Upper Peninsula, the fauna of the Ste. Mary's river and of Lake Superior is entirely boreal in its character. The fauna of the Menominee river, the dividing line between Michigan and Wisconsin, on the other hand is composed of the Mississippian species that here, apparently, reach their northern limit. Whether this is exactly correct or not, we do not know as the several rivers flowing into Lake Michigan between the Menominee and the Straits of Mackinac are wholly unexplored. We should like to know what the faunas of these rivers are and, when the dividing line between these two faunal areas is definitely determined, to know what the environmental conditions are that fix that limit and prevent these southern species from creeping around and obtaining a foothold in the Ste. Mary's river. This is only one of several questions involved in the same inquiry.

In the same way, in the Lower Peninsula, the Saginaw-Grand Valley is apparently the northern limit of the range of most of the southern fauna that fill the waters of the counties lying south of that valley. We should like to know whether this is true and, if it is the fact, then, why it is so. But, unfortunately, scarcely anything is known in regard to the fauna of the counties occupying the central part of the state north of the Saginaw-Grand Valley, and we are blocked in our attempts to find an adequate explanation for this, apparent, fact by the almost entire lack of the data that we should have to enable us to undertake the consideration of the problem with any assurance of satisfactory results.

These are but samples of many similar problems that appeal to the student of faunistics. And it would seem eminently proper that, so far as it can, the Survey should, in the future, plan its work with reference to these broader questions that appeal to the philosophical naturalist.

All this has reference to the purely scientific work of the Survey. But it seems to me that there is another field of endeavor, of even greater importance, that should appeal to the Survey, if it has the real scientific interests of the people of this state at heart. I refer to its possible relations to our educational system and, if you please. to popular natural history. And I speak of it in this connection because it seems to me that the department that I represent is most admirably adapted for that class of work.

In 1855, there were in the city of Grand Rapids, alone, four students of conchology and probably as many more in different parts of the state. In the year of grace, 1911, so far as I know, there are only three persons in the whole state of Michigan, who are actively interested in the collection and study of our mollusca. Thirty years ago, there was not a single special teacher of natural science in any school in the state. Today, even the second rate high schools have at least one. Today, hundreds of scholars in our schools receive some sort of instruction in natural science. Whereas a generation ago, no such instruction was even attempted. Nevertheless, though during the seventeen years that this society has had its regular annual meetings, like "a voice in the wilderness," I have proclaimed the special advantages and opportunities for work afforded by my specialty, in all that time, I have not had a single inquiry from any high school teacher in this state expressing any personal interest in the subject and only one from a teacher requesting information for a scholar. If this indifference were confined to conchology alone, it might charitably be ascribed to the forbidding nature of the subject, without necessitating any reflections upon the qualifications of its advocate, but, as I have reason to believe it is equally true in regard to all the other branches of botany and zoology, with the possible exception of ornithology. So far as I have been able to ascertain, during the last twenty years, there has not been a single fact added to our knowledge of our flora and fauna by the high school teachers of this state. If this is true, it is certainly a lamentable fact and I fear that it is so near the truth as to be a serious criticism of our present methods of instruction. It would seem as though the love of nature played no part in the equipment of a successful teacher of biology. And, indeed, it would almost seem that the present method of biological instruction in our schools was actually inimical to the acquisition of any practical and intelligent interest in natural history. If the object of our present system is to evolve, by a process of more or less natural selection, the biological teachers for the next generation, then presumably it is more or less successful. But if its purpose is the greatest good to the greatest number of students, if its object is to lay the foundation for an active and intelligent interest in the world lying about us that shall be a source of inspiration and pleasure in after life, then it certainly seems to me that it is questionable whether it does justify its existence.

The study of the classics in our schools and colleges, has through "dry-as-dust," antiquated and impractical methods of instruction, become, at the present time, an almost inappreciable element in our system of education. It would be a sad day, if, in the not distant future, our methods of scientific instruction should likewise be weighed in the balance and found wanting.

I would, therefore, plead for more natural history of the old fashioned kind and for more nature study, even of the fakish kind, and less morphological biology with Mendelian variations in our schools and even in our colleges. For as the proverb runs, "The fathers have eaten sour grapes and the children's teeth are set on edge," which, by the way, is a pretty clear statement of the doctrine of the inheritance of acquired characteristics for 500 B. C.

But, even, if this is not true and the real cause is to be sought elsewhere, the great dearth of popular interest in natural science during the last twenty years seems to be a fact that must be recognized and deplored. The recent increase in favor of "nature study" as it is called in popular language or "Ecology" in scientific nomenclature, would seem to be a revival in modern dress of the old-time natural history and may, indeed, be the swing of the pendulum back toward its original starting point. And, in so far as it tends to popularize science and to create an active and intelligent interest among all classes of the community in our animals and plants and all the various phenomena of animated nature, it is certainly deserving of the support of all who have the real interests of science at heart. For, without the popular support that comes from an intelligent appreciation of the methods, purposes and results of scientific investigation, pure science and the interests of higher, technical scientific education will still continue to lack that hearty and generous recognition from the people and their representatives, to which they are entitled.

It is along these lines of popular education in science that it would seem eminently proper that the Survey should to some extent, at least, direct its efforts. The collection and distribution among the high schools of the state of proper material for illustrating the characteristic elements of our flora and fauna; the publication of manuals and of literature, not too technical and even along popular lines, on ecological and other subjects calculated to stimulate an interest in all branches of natural science and a cordial and systematic co-operation with the teachers of the state in their work of instruction would do much to create a volume of public opinion that could not fail to have a favorable influence upon the advancement of science in all of its departments. And in thus lending its knowledge and influence to the cause of popular education, it would certainly seem that the survey would justify its existence at the bar of public opinion.

Detroit, Mich., April, 1911.

A CHECK-LIST OF MICHIGAN MOLLUSCA.

BRYANT WALKER.

PREFACE.

The last general catalogue of the mollusca of the state was published in 1884. During the seventeen years that have elapsed since that time, not only has the number of species known to inhabit the state been largely increased, but the advance in systematic conchology has resulted in many changes in classification and specific nomemclature.

The constantly increasing size of the known fauna of the state is shown by the following summary of the several general catalogues that have been published since the first, in 1839. All synonyms and obviously erroneous citations have been omitted and the comparison is based on the accepted nomenclature of the present time.

Name.	Date.	Land.	Fresh Water Pulmonates.	Fresh Water Operculates.	Bivalves.	Total.
Sager	1839	23	10	4	26	63
Miles	1860	44	24	14	48	130
Currier	1868	44	34	12	52	142
DeCamp	1881	48	38	23	68	177
Walker	1894	71	51	31	81	234
Walker	1911	83	67	33	118	301

In view of these facts, it has seemed probable that a check-list, brought down to date, might be of service to those interested in our local fauna.

Detroit, March 1, 1911.

CHECK-LIST.

1. *Acanthinula harpa* (Say).
2. *Vallonia costata* (Müll.).
3. *excentrica* Sterki.
4. *pulchella* (Müll.).
5. *Polygyra albolabris* (Say).
   dentata (Tryon.).
   maritima Pils.
6. *clausa* (Say).
7. *elevata* (Say).
8. *fraudulenta* Pils.
9. *fraterna* (Say).
10. *hirsuta* (Say).
11. *inflecta* (Say).
12. *mitchelliana* (Lea).
13. *monodon* (Rack.).

14. *Polygyra multilineata* (Say).
alba (Witt.).
rubra Witt.).
15. *palliata* (Say).
16. *pennsylvanica* (Green).
17. *profunda* (Say).
alba (Walk.).
18. *sayana Pils.*
19. *thyroides* (Say).
20. *tridentata* (Say).
21. *zaleta* (Binn.).
22. *Strobilops affinis* Pils.
23. *labyrinthica* (Say).
24. *virgo* (Pils.).
25. *Pupoides marginatus* (Say).
26. *Bifidaria armifera* (Say).
affinis Sterki.
similis Sterki.
27. *clappii* Sterki.
28. *contracta* (Say).
29. *corticaria* (Say).
30. *pentodon* (Say).
•31. *tappaniana* (C. B. Ads.).
32. *Pupilla muscorum* (L.).
33. *Vertigo bollesiana* (Mse.).
34. *gouldii* Binn.
35. *milium* Ged.
36. *morsei* Sterki.
37. *ovata* Say.
38. *tridentata* Wolf.
39. *ventricosa* (Mse.).
elatior Sterki.
40. *Cochlicopa lubrica* (Müll.).
41. *Circinaria concava* (Say).
42. *Omphalina fuliginosa* (Griff.).
43. *inornata* (Say).
44. *Vitrina limpida* Gld.
45. *Vitrea binneyana* (Mse.).
46. *cellaria* (Müll.).
47. *ferrea* (Mse.).
48. *hammonis* (Ström).
49. *indentata* (Say).
50. *multidentata* (Say).
51. *rhoadsi* Pils.
52. *wheatleyi* (Bld.).
53. *Euconulus chersinus polygyratus* Pils.
54. *fulvus* (Müll.).
55. *Zonitoides arborea* (Say).
56. *exigua* (Stimp.).
57. *limatula* (Ward).
58. *milium* (Mse.).
59. *minuscula* (Binn.).
60. *nitida* (Müll.).

61. *Gastrodonta demissa* (Binn.).
62. *intertexta* (Binn.).
63. *ligera* (Say).
64. *suppressa* (Say).
65. *Agriolimax agrestis* (L.).
66. *campestris* (Say).
67. *Philomycus carolinensis* (Bosc.).
68. *Pallifera dorsalis* (Binn.).
69. *hemphilli* (W. G. Binn.).
70. *Pyramidula alternata* (Say).
alba (Tryon).
71. *asteriscus* (Mse.).
72. *cronkheitei albina* ("Mse." Ckll.).
anthonyi Pils.
catskillensis Pils.
73. *perspectiva* (Say).
74. *solitaria* (Say).
75. *Helicodiscus parallelus* (Say).
76. *Punctum pygmæum* (Drap.).
77. *Sphyradium edentulum* (Drap.).
78. *Succinea avara* Say.
alba Ckll.
major W. G. Binn.
vermeta Say.
79. *concordialis* Gld.
80. *ovalis* Say.
optima Pils.
81. *retusa* Lea.
decampii Tryon.
magister Pils.
peoriensis Wolf.
82. *Carychium exiguum* (Say).
83. *exile* H. C. Lea.
canadense Clapp.
84. *Lymnæa apicina* Lea.
85. *bakeri* Walker.
86. *caperata* Say.
87. *catascopium* Say.
88. *columella* Say.
chalybea Gld.
89. *contracta* "*Curr.*" DeCamp.
90. *cyclostoma* Walker.
91. *elodes* Say.
jolietensis Baker.
92. *exilis* Lea.
93. *dalli* Baker.
94. *davisi* Walker.
95. *emarginata* Say.
angulata Sby.
canadensis Sby.
ontarioensis "Muhl." Kust.
wisconsineusis Baker.

96. *Lymnæa galbana* Say.
97. *haldemani* "Desh.," W. G. Binn.
98. *humilis modicella* Say.
rustica Lea.
99. *kirtlandiana* Lea.
100. *lanceata* Gld.
101. *megasoma* Say.
102. *nasoni* Baker.
103. *obrussa* Say.
decampii Streng.
exigua Lea.
peninsulæ Walker.
104. *pallida* C. B. Ads.
105. *palustris* Müll.
alpenensis Baker.
zebra Taylor.
106. *parva* Lea.
107. *petoskeyensis* Walker.
108. *pilsbryana* Walker.
109. *reflexa* Say.
walkeri Baker.
zebra Tryon.
110. *stagnalis appressa* Say.
lillianæ Baker.
perampla Walker.
sanctæ-mariæ Walker.
111. *umbilicata* C. B. Ads.
112. *woodruffi* Baker.
113. *Physa anatina* Lea.
114. *ancillaria* Say.
crassa Walker.
magnalacustris Walker.
115. *brevispira* Lea.
116. *crandalli* Baker.
117. *deformis* Curr.
118. *elliptica* Lea.
minor Crandall.
119. *gyrina* Say.
hildrethiana Lea.
oleacea Tryon.
120. *heterostropha* Say.
121. *integra* Hald.
billingsii Heron.
122. *lordi* Bd.
123. *niagarensis* Lea.
124. *pomilia showalteri* Lea.
125. *sayii* Tapp.
warreniana Lea.
126. *vinosa* Gld.
127. *walkeri* Crandall.

128. *Aplexa hypnorum* (L.).
glabra (DeKay).
tryoni (Curr.).
129. sp.?
130. *Planorbis bicarinatus* Say.
aroostookensis Pils.
corrugatus Curr.
percarinatus Walker.
portagensis Baker.
royalensis Walker.
striatus Baker.
131. *campanulatus* Say.
minor Dkr.
rudentis Dall.
132. *corpulentus* Say.
133. *crista* L.
134. *deflectus* Say.
135. *exacuous* Say.
136. *hirsutus* Gld.
137. *multivolvis* Case.
138. *parvus* Say.
walkeri Van.
139. *trivolvis* Say.
binneyi Tryon.
140. *truncatus* Miles.
141. *umbilicatellus* Ckll.
142. *Segmentina armigera* (Say).
143. *crassilabris* Walker.
144. *Ancylus fuscus* C. B. Ads.
eugraptus Pils.
145. *kirklandi* Walker.
146. *parallelus* Hald.
147. *rivularis* Say.
148. *shimekii* Pils.
149. tardus Say.
150. walkeri P. & F.
151. *Valvata bicarinata connectans* Walker.
perdepressa Walker.
152. *lewisii* Curr.
153. *sincera* Say.
nylanderi Dall.
154. *tricarinata* Say.
confusa Walker.
simplex Gld.
unicarinata DeKay.
155. *Vivipara contectoides* W. G. Binn.
156. *Campeloma decisa* (Say).
flava Curr. Mss.
melanostoma Curr. Mss.
157. *integra* (Say).
158. *milesii* (Lea).
159. *obesa* (Lewis).

160. *Campeloma rufa* (Hald.).
gibba (Curr.).
161. *subsolida* (Anth.).
162. *Bythinia tentaculata* (L.).
163. *Paludestrina nickliniana* (Lea).
attenuata (Hald.).
164. sp.?
165. *Somatogyrus subglobosus* (Say).
166. *Amnicola cincinnatiensis* Anth.
167. *emarginata* Küst.
168. *letsoni* Walker.
169. *limosa* (Say).
porata (Say).
170. *lustrica* Pils.
171. *walkeri* Pils.
172. *Lyogyrus pupoideus* (Gld.).
173. *Pomatiopsis cincinnatiensis* (Lea).
174. *lapidaria* (Say).
175. *Pleurocera subulare* (Lea).
intensum (Rve.).
176. *clevatum* (Say).
177. *neglectum* (Anth.).
178. *Goniobasis brevispira* (Anth.).
179. *depygis* (Say).
180. *gracilior* (Anth).
181. *livescens* (Mke.).
translucens (Anth.).
182. *pulchella* (Anth.).
183. *semicarinata* (Say).
184. *Truncilla perplexa rangiana* (Lea).
185. *sulcata delicata* Simp.
186. *triquetra* Raf.
triangularis (Bar.).
187. *Micromya fabalis* (Lea).
188. *Lampsilis alata* (Say).
189. *ellipsiformis* (Con.).
190. *glans* (Lea).
191. *gracilis* (Bar.).
192. *iris* (Lea).
193. *lævissima* (Lea).
194. *leptodon* (Raf.).
195. *ligamentina* (Lam.).
196. *luteola* (Lam.).
roseacca (DeKay).
197. *multiradiata* (Lea).
198. *nasuta* (Say).
199. *parva* (Bar.).
200. *recta* (Lam.).
sageri (Con.).
201. *superiorensis* (Marsh).
202. *ventricosa* (Bar.).
canadensis (Lea).

203. *Obovaria circula* (Lea).
204. *ellipsis* (Lea).
205. *leibii* (Lea).
206. *lens* (Lea).
207. *Plagiola donaciformis* (Lea).
208. *elegans* (Lea).
209. *Obliquaria reflexa* Raf.
210. *Ptychobranchus phaseolus* (Hild.).
211. *Strophitus edentulus* (Say).
pavonia (Lea.).
rhombica (Anth.).
212. *Anodonta corpulenta* Coop.
213. *grandis* Say.
benedictensis Lea.
footiana Lea.
gigantea Lea.
214. *imbecilis* Say.
215. *kennicottii* Lea.
216. *marginata* Say.
217. *subgibbosa* Anth.
219. *Anodontoides ferussaciana* (Lea).
modesta (Lea).
subcylindracea (Lea).
220. *Symphynota complanata* (Bar.).
221. *compressa* Lea.
222. *costata* (Raf).
223. *Alasmidonta calceola* (Lea).
224. *marginata* (Say).
varicosa (Lam.)
225. *Hemilastena ambigua* (Say).
226. *Unio complanatus* (Dill.).
227. *gibbosus* Bar.
228. *Quadrula coccinea* (Con.).
229. *kirtlandiana* (Lea.)
230. *lachrymosa* (Lea).
231. *plicata* (Say).
232. *pustulosa* (Lea).
233. *rubiginosa* (Lea).
234. *tuberculata* (Raf.).
235. *undata* (Bar.).
236. *undulata* (Bar.).
hippopea (Lea).
237. *Sphærium aureum* (Pme.).
238. *crassum* Sterki.
239. *emarginatum* (Pme.).
240. *fabale* (Pme.).
241. *flavum* (Pme.).
242. *lineatum* Sterki.
243. *occidentale* Pme.
244. *rhomboideum* (Say).
245. *simile* (Say).
246. *solidulum* (Pme.).

247. *Sphærium stramineum* (Con.).
248. *striatinum* (Lam.).
249. *tenue* (Pme.).
250. *Musculium partumeium* (Say).
251. *rosaceum* (Pme.).
252. *ryckholtii* Norm.
253. *securis* (Pme.).
cardissum (Pme.).
croceum (Lewis).
254. *sphæricum* (Anth.).
255. *transversum* (Say).
256. *truncatum* (Lind.).
257. *Pisidium abditum* Hald.
258. *abyssorum* Stimp.
259. *adamsi* Pme.
260. *aequilaterale* Pme.
261. *affine* Sterki.
262. *atlanticum* Sterki.
263. *complanatum* Sterki.
264. *compressum* Pme.
arrosum Sterki.
confertum Sterki.
rostratum Sterki.
lævigatum Sterki.
265. *contortum* Pme.
266. *costatum* Sterki.
267. *cruciatum* Sterki.
268. *cuneiforme* Sterki.
269. *fallax* Sterki.
errans Sterki.
mite Sterki.
270. *handwerkerii* Sterki.
271. *idahoense* Sterki.
272. *imbecile* Sterki.
273. *kirklandi* Sterki.
274. *levissimum* Sterki.
275. *mainense* Sterki.
276 *medianum* Sterki.
minutum Sterki.
277. *milium* Held.
278. *monas* Sterki.
279. *neglectum* Sterki.
corpulentum Sterki.
280. *noveboracense* Pme.
expansum Sterki.
fraternum Sterki.
lineatum Sterki.
281. *ohioense* Sterki.
282. *pauperculum* Sterki.
283. *peraltum* Sterki.
284. *politum* Sterki.

285. *Pisidium punctatum* Sterki.
armatum Sterki.
simplex Sterki.
286. *roperi* Sterki.
287. *rotundatum* Pme.
288. *sargenti* Sterki.
289. *scutellatum* Sterki.
290. *splendidulum* Sterki.
291. *strengii* Sterki.
292. *subrotundum* Sterki.
293. *succineum* Sterki.
294. *superius* Sterki.
295. *tenuissimum* Sterki.
296. *trapezoideum* Sterki.
297. *variabile* Pme.
brevius Sterki.
298. *ventricosum* Pme.
299. *vesiculare* Sterki.
300. *virginicum* (Gmel.).
301. *walkeri* Sterki.

Detroit, Mich., March 1, 1911.

NOTES ON MICHIGAN CRUSTACEA. I.

A. S. PEARSE.

In the twelfth report of this Academy, the writer published a preliminary list of the crustacea of Michigan.[1] Although every effort was made to include all references to the carcinological fauna of this state, one paper by E. B. Williamson[2] was overlooked. The localities mentioned by this author are, therefore, included in the present paper. During the past year the University of Michigan Museum has received crustaceans from several sources, and, although no new species for the state have been secured, the ranges of several have been extended. The following records represent new localities for the species listed:

CLADOCERA.

Bosmina longirostris O. F. M. Douglas Lake, Cheboygan County.
Daphnia hyalina Leydig. Douglas Lake, Cheboygan County.
Leptodora hyalina Lilljeborg. Douglas Lake, Cheboygan County.
Polyphemus pediculus Linn. Douglas Lake, Cheboygan County.

COPEPODA.

Cyclops bicuspidatus Claus. Douglas Lake, Cheboygan County.
Epischura lacustris Forbes. Douglas Lake, Cheboygan County.

AMPHIPODA.

Gammarus limnaeus Smith. Carp Creek, Cheboygan County.

DECAPODA.

Cambarus argillicola Faxon. Douglas Lake, Cheboygan County. This record is of particular interest for the species has not previously been recorded farther north than Saginaw and Gratiot Counties.

Cambarus bartoni robustus (Girard). Charity Islands and Port Austin in Huron County; Ionia County. Williamson (*op. cit.*) found *C. bartoni* north of Sault Ste. Marie in Canada, but all the specimens from Michigan are of the variety *robustus*. However, no representatives of this species have as yet been taken in Michigan from Lake Superior.

Cambarus propinquus Girard. Charity Islands and Port Austin in Huron County; Cass, Chippewa, (Williamson, *op. cit.*) and Ionia Counties.

Cambarus virilis Hagen. Emmet County (Williamson, *op. cit.*).

Ann Arbor, Mich., April, 1911.

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[1]Pearse, A. S. 1910. A Preliminary List of the Crustacea of Michigan. 12th Rept. Mich. Acad Sci., pp. 68-76.

[2]Williamson, E. B. 1907. A Collecting Trip North of Sault Ste. Marie, Ontario. Ohio Natur., Vol. 7, pp. 129-148.

RESULTS OF THE MERSHON EXPEDITION TO THE CHARITY ISLANDS, LAKE HURON.

MAMMALS.

N. A. WOOD.

This paper is one of a series that is to appear on the flora and fauna of the Charity Islands, as a result of investigations made by the different members of the Mershon Expedition of the University of Michigan Museum. A general account of the expedition has already appeared.[1] It is sufficient here to state that the work was made possible by the generosity of Hon. W. B. Mershon of Saginaw, Michigan, and was carried on, during the late summer of 1910, by six men, each of whom gave his attention to a particular group. The writer had charge of the vertebrate work, and, although the island is almost devoid of mammalian life and most of his attention was given to the birds,[2] he made an effort to secure as accurate a knowledge as possible of the mammals.

The writer wishes to acknowledge the assistance of the light-house keeper, Captain C. C. McDonald, and his assistant, Joseph Singleton, both in collecting specimens and in furnishing data on species which they have noted on the islands. Captain McDonald's notes are particularly valuable for he has spent nine entire years on Charity Island and for twenty years has lived a part of each year there.

The Charity Islands are situated near the mouth of Saginaw Bay, in latitude 44° north. There are three islands in the group. Charity Island proper contains about six hundred and fifty acres, Little Charity, the next largest, about three acres, and Gull Island is a small projecting reef, about a quarter of an acre in extent, that is not usually shown on the maps. The islands are somewhat nearer the west coast than the east. Charity Island is six and seven-eighths miles southeast of Point Lookout on the north shore, and nine and five-eighths miles northwest of Caseville, seven and three-fourths miles north of Sand Point, and nine miles northwest of Oak Point on the south shore.

Geologically the foundation of the islands is Maxwell sandstone. On Charity Island this outcrops as ledges on the north and east sides, but it also appears on the other sides, especially on the points, which are bare rock. The surface is covered with sand driven up by the action of winds and waves into fossil beaches and sand dunes. The island is being enlarged continually by the addition of sand flats, especially on the west side, where a large bar of many acres in extent is now almost at the surface of the water. Little Charity Island is of much the same character, and Gull Rock is a low rocky islet covered with sand.

Fortunately for our work, Charity Island is a light-house station, and hunting and fishing within one mile of its shores, and the cutting of the vegetation are not permitted. The conditions are thus quite primitive

[1] Ruthven, Alexander G. Science, N. S., XXXIII, pp. 208-209.
[2] Wilson Bulletin, Vol. XXIII, pp. 78-112.

except in the immediate vicinity of the light. The dominant forest is red oak with some hard and soft maple, principally on the north and east sides near the shore. In the latter place there is also a large beech tree, the only one on the islands, and a few cottonwoods. Scattered throughout the interior are groups and single trees of white and Norway pine, white birch and poplar, and around the edges of a small lagoon or pond near the west side are a few small tamaracks and one jack pine, the latter also the only tree of its kind on the island. Near the center of the island there are a few small hemlock trees, and along the present beaches juniper and small willows are to be found.

Little Charity Island is privately owned and is used for a fishing station. The effect of this upon the fauna and flora is well marked. The large trees have been cut, and it has nearly all been burned over. It is now grown up to bushes, only a few large hackberry trees and groups of smaller ones, with a few old oaks and some small willows and poplars, representing the forest that once grew there. Gull Rock is mostly without vegetation, but a few small willows and balsam-poplars grow on one end of it.

Owing to the fact that these islands have had no land connection with the east or west shores of the bay since the glacial period, it is not surprising that but few species of indigenous mammals occur in the group. The native species are red fox, American hare, cottontail, Say's brown bat, silver-haired bat, red bat and muskrat (one record). It is easy to see how most of the species reached the islands from the mainland. The American hare, cottontail and fox cross over on the ice in winter. In fact, Captain McDonald informed us that he has seen all of these species on the ice. He has noted the tracks of the hare and cottontail leading from the mainland to the island, and has seen foxes come to the island from the mainland. The raccoon and fox squirrel were introduced by man. It is not definitely known how the single muskrat that was observed on Charity Island reached there, but it is safe to conclude that it either swam there or crossed on the ice, with the probabilities in favor of the latter method. The bats, of course, fly over.

LIST OF SPECIES.

1. *Vulpes fulvus* (Desmarest). Red Fox.—The fox is apparently not a regular resident on the islands. Captain McDonald informed us that in the winter of 1902-3 a pair of red foxes took up their abode on Charity Island and found good living on the hares and cottontails which were then common. The ice broke up early in the spring so that the pair could not get off the island. In the spring they had caught off most the hares and began to catch the poultry, so a hunter and hound were brought over from Caseville. One fox was shot and the other was dug out of her den (a burrow in the ground, where she was rearing three young). No others have been known to breed on the island, but they no doubt have done so occasionally, although the island could not furnish food for any length of time to even one family of such carnivors. Captain McDonald informed us that, when chased by hounds in the winter, foxes often cross the bay, and one winter as he was spearing, a couple of miles from the island, he saw a fox approaching on the ice.

2. *Lepus americanus* Erxleben. Varying Hare.—This hare was found

on Charity Island by the writer, but it was not common and was seen on but two occasions. Two were shot by the keepers in November after the party had left the island. This species has lived on Charity Island during the twenty-nine years that Captain McDonald has had charge of the light and at times became very common. In the winter of 1902-3, three great horned owls came to the island and, finding this species common, stayed there and lived upon it until by spring, between the owls and foxes, it was nearly exterminated. It has not been common since that date. It has not been observed on Little Charity and of course not upon Gull Rock.

3. *Sivilagus floridanus mearnsi* Allen. Cottontail.—The cottontail has never been very abundant on Charity Island. Only two were seen by the writer, one a very young one. On Little Charity it is quite common, for example, on November 29, 1909, Captain McDonald and his assistant, Mr. Singleton, shot ten in a short time.

4. *Fiber zibethicus* (Linn.). Muskrat.—A single muskrat has been seen (1909) by the keepers, in the pond on Charity Island. The writer found the tunnels in several places about the edge of the pond, but none seemed to be in use, and no tracks were observed. Although the pond is of good size, it is almost entirely devoid of the aquatic plant food necessary to the life of this species and in winter must freeze solid, as the water is very shallow. It is thus very probable that the individual seen was a straggler that was unable to persist. It may have reached the island by swimming, but it more probably crossed on the ice. The species is known to cross long stretches of snow in the winter, and Mr. Singleton informed us that he saw one on the ice of the bay and miles from the nearest land.

5. *Sciurus niger rufiventer* (Geoffrey). Fox Squirrel.—The only squirrels of this species ever known on the islands were the offspring of two pair that were brought to Charity Island, in 1896, from Caseville, Michigan, by Mr. Singleton. This pair thrived and multiplied to such an extent that in 1902 they became a nuisance to the keepers, as they ate the fruits and vegetables in the garden. A few were shot and used for food, and for some reason the remainder all died during the following winter. Captain McDonald told the writer that in the spring many dead ones were found but without marks of injury. Apparently the only available food for the species on the island would be acorns and the seeds of the Norway and white pine (and perhaps the seeds of the poison ivy). The year 1902 may have been one when no acorns were grown, or, like that of 1910, one when they were mostly imperfect or wormy. In 1910, the trees were full of apparently good acorns, but, although a great many were examined very few sound ones were found.

6. *Procyon lotor* (Linn.). Raccoon.—The writer often saw the tracks of this species on the beaches of Charity Island, where the animals went to feed on the crayfish and clams among the rocks, and where too they often found injured fish that had been cast up by the waves. The first coons were brought to the island in the summer of 1906 by Mr. Paul Deford, of Caseville, who released five of them. As there is plenty of food and many old trees with large cavities for shelter, the species has increased so that during the fall of 1909, the keepers, hunting them with the aid of a hound, were able to secure fifteen. It was thought best not to further reduce the number, so none were taken

during the fall of 1910. The raccoon has no enemy but man on the island, and the keepers can regulate the number to suit the food conditions.

7. *Myotis sublatus* (Say). Say's Bat.—This species was rather common about the light-house clearings on Charity Island and lived in some old buildings near the light. Nearly every evening after sundown one or more were seen as they flew once or twice around the light-house, and then down along the beach over the water or at the edge of the forest. On the night of September 6, a hard thunder-storm occurred which lasted till morning. The outside door of the workshop was left open, and, when the writer went to close it at daylight, eight bats, all of this species, were found hanging to the side of the house behind it. A few were seen as late as October 14, and some of them probably stay all winter and hibernate as they have been found to do at Ann Arbor.

8. *Lasionycteris noctivagans* (Le Conte). Silver-haired Bat.—This bat was often seen flying about the light-house clearing on Charity Island. It seemed to hunt closer to the edge of the woods than the preceding species. It was not seen inside of the buildings and no doubt lived in the forest. There seemed to be a migration on the evening of September 3, for at that time great numbers were seen in the clearing about the light-house. Several were shot and all were of this species. Previous to this time only one or two pair had been seen, and none were seen again during our stay on the island. This flight may have consisted of island individuals that had collected preparatory to migrating, or it may have been a movement of mainland individuals.

9. *Lasiurus borealis* (Muller). Red Bat.—The red bat is apparently rare in the Charities as only a few were seen. Single specimens were shot on August 23 and 27, as they were flying about the light-house clearing on Charity Island.

Ann Arbor, Mich., April, 1911.

NOTES ON A PALAEMON FROM KAMERUN.

A. S. PEARSE.

There is a single male specimen (Catalog No. 38875) of the shrimp, *Palaemon* (*Macrobrachium*) *jamaicensis* (Herbst) var. *vollenhovenii* (Herklots) in the University of Michigan Museum. It was collected at Efulan, Kribi, Kamerun, West Africa, by Mr. George Schwab. As little material of this species has been examined from the Kamerun region, the following data concerning this specimen may be of interest.

Rostral formula	$\frac{11}{4}$
Total length	135 mm.
Length of right second leg	120 mm.
Length of merus	22 mm.
Length of carpus	19.5 mm.
Length of hand	58 mm.
Palm-length	32 mm.
breadth	8 mm.
thickness	7 mm.
Length of fingers	26 mm.

Ann Arbor, Mich., April, 1911.

OBSERVATION ON THE MAMMALS OF THE DOUGLAS LAKE REGION, CHEBOYGAN COUNTY, MICHIGAN.*

ORRIN J. WENZEL.

Douglas Lake lies in the northern part of the southern peninsula of Michigan, about eighteen miles south of Mackinaw City and about twelve miles east of the city of Cheboygan.

In general, the region is an old pine "slashing" which at present is covered by white birch, brake ferns, and a few huckleberry and blackberry bushes. Occasionally one finds a small patch of hardwood or a cedar swamp to break the monotony of the sandy "pineries," and along the shores of the lake are to be seen in places fringes of tall pines which have either escaped the axes of lumbermen or found conditions more favorable for growth after they had passed. One or two sphagnum bogs are also to be found within two miles of Douglas Lake.

In this varied region, the University of Michigan maintains its Summer Biological Station, and it is here that the writer had occasion to make a few observations on the mammals of the region along with other work carried on at the station. An attempt was made to study the animals at certain stations. The latter were chosen arbitrarily but each one selected differed in some respects from the others. They were all so nearly alike, however, that no very striking results were obtained by this method.

The specimens taken are in the University of Michigan Museum, and the numbers in the list of species are those which have been given to them in the museum catalogs. It is hardly necessary to state that this paper gives but an incomplete idea of the mammalian life of the Douglas Lake region. The writer believes, however, that the records obtained are reliable and trusts that as a preliminary report this paper will prove of some assistance both to those interested in the mammalian life of the region and students of the general fauna of the state.

I wish to acknowledge my indebtedness to Dr. A. S. Pearse and Dr. A. G. Ruthven for helpful suggestions and criticisms both in the field work and in the preparations of this paper.

LOCATION OF STATIONS.

Station I. This station was the immediate region of the camp. The soil was sandy and overgrown with brake ferns, huckleberry bushes, and white birch with a row of tall pines along the shore of the lake. Here only white-footed mice, chipmunks, and occasionally, though rarely, a red squirrel were taken.

Station II. The area comprised in this station was what is known as Grape-vine Point. Nearest the water's edge is an alluvial flat cov-

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*Contributions from the Zoological Laboratory of the University of Michigan, No. 133. (Biological Station Series, Zoological Publication No. 3).

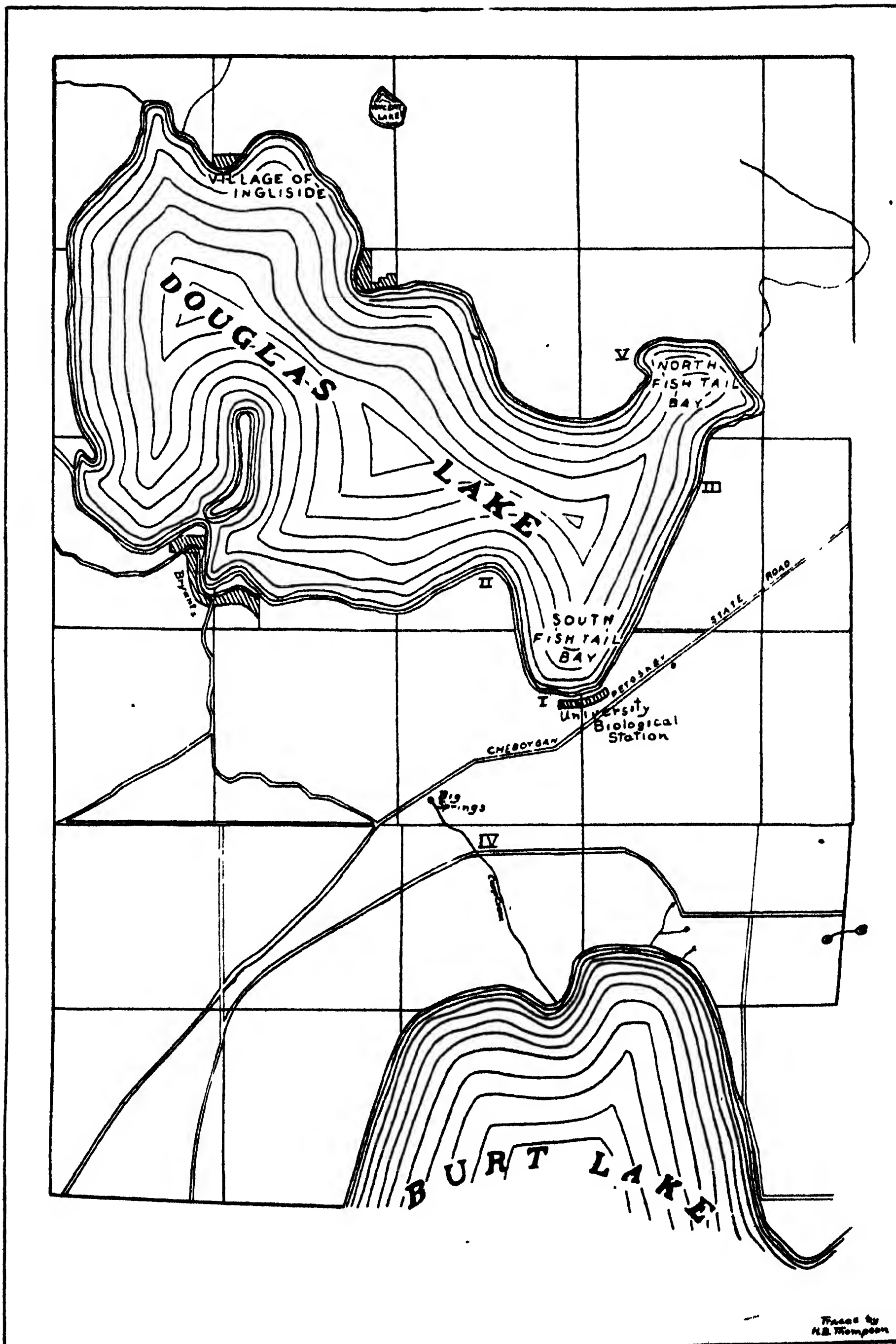
ered by a nearby pure stand of white birch under which mosses and liverworts (*Funaria* and *Marchantia*) grow in the greatest abundance. Back of this, there is a sharp rise of ground covered by dense hard woods, mostly maple. The trees gradually become smaller as one leaves the lake and they are finally replaced by a dense growth of under-brush. Here were found white-footed mice, chipmunks, and red squirrels in abundance; and less frequently flying squirrels, raccoons, and deer.

Station III. For the third station a point of land northeast of the station on the shores of the lake was chosen. At this place, a strip of pine fifty feet wide extends along the shores of the lake. Back of the pines are poplar and white birch and a slight depression in which willows grow. At this place red squirrels, chipmunks, white-footed mice, hares, and the short-tailed shrew were found, and both foxes and deer came almost every night to the beach at this point.

Station IV. A swamp near the "Big Springs" was selected for the fourth station. Cedar, balsam and spruce were the principal trees; under these was a very thick soft carpet of sphagnum moss. In this place, white-footed mice, chipmunks and one Cooper's lemming vole were taken.

Station V. The fifth station selected was the hardwood forest north of the lake. Along the water's edge were found overhanging birches and back of this was a natural terrace on which almost nothing but hemlock grew. Back of the hemlock, was a virgin forest of hardwood in which a few scattering hemlocks were found. At the west end of North Fishtail Bay, there was a piece of low ground covered with cedar, birch, and ash in abundance; cedar being the most plentiful. It was in this cedar swamp that the only specimen of red-backed mouse was taken. This was the best mammal station of all and the farthest from the Biological Camp. Records or specimens of the following forms were obtained: deer, red squirrels, fox squirrels, black and gray squirrels, flying squirrels, muskrats, porcupines, red-backed mice, skunks, red foxes, raccoons, white-footed mice, bats, and hares.

The location of the stations is shown on the accompanying sketch map.


VILLAGE OF INGLISIDE
DOUGLAS LAKE
NORTH FISH TAIL BAY
SOUTH FISH TAIL BAY
V
III
II
I
IV
Bryants
University Biological Station
CHEBOYGAN
PETOSKEY
STATE ROAD
Big Springs
BURT LAKE
Traced by H.B. Thompson

LIST OF SPECIES.

1. *Odocoileus americanus borealis* Müller. Northern White-tailed Deer.—Deer are quite common in the region of Douglas Lake. The writer saw five during the eight week's session of the summer school, and several more were seen by other students. Two or three came out to the lake, to eat the water vegetation or to drink, almost every night during the summer.

2. *Sciurus niger rufiventor* (Geoffrey). Western Fox Squirrel.—This species was not found to be very abundant, perhaps for the reason that the country is as yet too sparsely settled. The fox squirrel in Michigan, unlike the gray and black squirrels which retreat before the settlements, is found in groves and in small tracts of timber in the older settled regions. No specimens were taken, but farmers and hunters reported their presence.

3. *Sciurus carolinensis leucotis* (Gapper). Northern Gray or Black Squirrel. This species was found in great abundance in the hardwood timber north of the lake. Three specimens were taken, two of which were deep black. Many more were seen, and it is interesting to note that of the ten specimens observed only four were gray and the rest black.

Mr. Norton, a man who has lived on Indian Point, Burt Lake, for a period of more than ten years, told the writer that a family of black squirrels live in a tree back of his cottage, and, as he never allowed anyone to molest them, he has had a good opportunity to observe their habits. The most interesting fact about these squirrels was that in the past ten years he had never seen one gray squirrel among the young of those living in that tree. When large squirrels were plentiful in Osceola county, the percentage of the black phase was even greater than is found at present in Cheboygan county. The writer has seen hunters bring in a bag of fifteen or twenty large squirrels and only one or two gray squirrels among them, the rest being black.

Museum Number.	Sex.	Color.	Length.	Tail.	Foot.
41390	Adult female	Black	469	215	64
41389	Adult Male	Black	464	204	64
41396	Adult female	Gray	430	205	69

4. *Sciurus hudsonicus loquax* (Bangs). Red Squirrel, Chickaree.—This squirrel was found in great abundance wherever there was any timber at all. In the hardwood and hemlock forest north of Douglas Lake, especially near the shore in a narrow belt of hemlock, the noise made by numbers of these little animals was almost deafening during the early hours of the morning.

Museum Number.	Sex.	Length.	Tail.	Foot.
41392	Adult male	306	120	45
41391	Adult female	295	107	45

5. *Tamias striatus lysteri* (Richardson). Lyster's Striped Chipmunk.—This species is even more abundant than the red squirrel, for it is not, like the latter, confined to the timber. It could be seen and heard almost anywhere where there was enough shrubbery to furnish cover. The individuals were not in the least shy. One started to climb over one member of the party while he was standing motionless watching for birds. Another student succeeded in taming a pair so that they came regularly into his tent to eat from his hands and pockets.

Museum Number.	Sex.	Length.	Tail.	Foot.	Ear.
41393	Adult male	223	76	33	15
	Adult male	215	79	30	18
41394	Adult female..	222	82	35	16
	Adult female..	240	95	35	20
41378	Adult female	252	91	35	18

6. *Marmota monax monax* (Linnaeus). Woodchuck.—Woodchucks were reported to occur around the farm meadows east of Douglas Lake. The writer who worked in the woods and "pineries" more than elsewhere was unable to find any very good records beyond the reports of the farmers, though an occasional old burrow left little doubt of their presence.*

7. *Sciuropteris sabrinus* (Shaw). Hudson Bay Flying Squirrel.—This species was reported by woodcutters to be very plentiful but all efforts to secure specimens were without success. In talking with lumbermen, the writer learned that it is not unusual for men to cut down hollow trees in which ten or more flying squirrels live. This points toward gregariousness at least during hibernation. Several were seen at night playing about in the tops of low trees and making long flights from one tree to another.

A nest was found not over nine feet from the ground in a rotten snag about eight inches in diameter. Members of the Biological Station discovered a family of flying squirrels in this stub during the summer of 1909, but in 1910 it had been abandoned. The nest was examined and found to be made almost entirely of wood fiber or inner bark shredded very finely.

8. *Peromyscus leucopus noveboracensis* (Fischer). Northern White-footed Deer Mouse.—This and the following species are very well represented around Douglas Lake. White-footed mice are so abundant that it is difficult to catch any of the rarer species of small mammals, for one is quite sure of finding his traps filled with these wood mice.

Museum Number.	Sex.	Length.	Tail.	Foot.
41384	Adult female	175	80	20
41386	Adult female..	180	90	21
	Adult male	161	71	20

*The writer has taken a specimen since this paper went to press.

9. *Peromyscus maniculatus gracilis* (Le Conte). Michigan Mouse.—As stated above, this species is a common form in the Douglas Lake region.

Museum Number.	Sex.	Length.	Tail.	Foot.
41385	Adult male	171	85	20
41387	Adult female.	177	88	20
41383	? female	145	61	19

10. *Microtus pennsylvanicus* (Ord.). Meadow Mouse.—This species was found to be quite plentiful in the meadows east of Douglas Lake. As one would expect, none were found in the woods and "pineries." Two specimens were taken.

Museum Number.	Sex.	Length.	Tail.	Foot.
41382	Adult male	145	43	21
	Adult male	160	47	21

11. *Fiber zibethicus* (Linn.). Muskrat.—Probably because Douglas Lake has a sandy beach nearly all around it, not many muskrats are found along its shores. A few live in a small bayou on the west side of North Fish-tail Bay. Negro River which lies east of Burt Lake has very swampy shores and is an ideal place for mink and muskrats, and they are found in great abundance there. The specimen taken was so well concealed among the lily pads that it required the aid of field glasses to ascertain its hiding place.

Museum Number.	Sex.	Length.	Tail.	Foot.
41395	Adult female	477	237	80
	Adult ?	478	235	78

12. *Synaptomys cooperi* Baird. Cooper's Lemming Vole.—This lemming looks much like the Pennsylvania meadow mouse, except that it has a very short tail and has grooves along the front of the front incisors. Its fur or hair is coarser and grayer than that of the meadow mouse. It is quite plentiful in the sphagnum bogs near Burt Lake and along Carp Creek. The writer has seen these little animals take to the water in Carp Creek and swim rapidly across the strong current apparently with the relative strength of the muskrat.

Museum Number.	Sex.	Length.	Tail.	Foot.	Ear.
41381	Male	114	18	19	11

13. *Evotomys gapperi* (Vigors). Gapper's Red-backed Vole.—One specimen of this species was taken in a cedar and sphagnum swamp north of North Fish-tail Bay. This is apparently the first record for the southern peninsula.

Museum Number.	Sex.	Length.	Tail.	Foot.
41379....	Adult female...	144	42	19

14. *Erethizon dorsatum* (Linnaeus). Canadian Porcupine.—Numerous records of porcupines were obtained, but no living specimens were taken. Wherever abandoned lumber camps were found, it was not unusual to find where porcupines had gnawed the boards, presumably for the salt found in them. Two dead animals were seen, one near Burt Lake and one north of Douglas Lake.

15. *Lepus americanus* Erxleben. Varying Hare.—This species seemed very plentiful in and around the swamps. Those caught were nearly always eaten (probably by foxes) out of the traps during the nights on which they were taken. Several were seen and signs were plentiful. Trappers asserted that a disease breaks out among the hares and kills great numbers of them every few years.

16. *Lynx ruffus* (Gueldenstaedt). Red Lynx.—The wild-cat, now quite uncommon in the Lower Peninsula of Michigan, may still be found in some of the denser swamps and thickets of Cheboygan County. A man working in a small mill on Burt Lake stated that he saw two wildcats in the swamp between Burt and Douglas Lakes during the summer of 1910.

17. *Urocyon cinereo-argenteus* (Schreber). Gray Fox.—Gray foxes are still found in the region of Douglas Lake, though they are far less plentiful than the red fox. Hahn* states that, at the present time, the gray foxes, in Indiana, have burrows similar to those of the red foxes, though they may have lived in hollow logs and old tree trunks in former times. The writer has been able to observe the habits of foxes for several years in Michigan and has never known of a gray fox when hunted to take refuge in a burrow. Almost invariably they "hole" in a hollow log, or, when hard pressed, in a log pile or under an upturned root.

18. *Vulpes fulva* (Desmarest). Red Fox.—Red foxes are very plentiful in Cheboygan County. A mile or two away from human habitations, they may be seen almost any evening on the shores of the lakes, where they come to feed on fish and mussels. White-footed mice and the varying hares probably furnish a large part of the natural food for the foxes of the region, as they are the only animals upon which they might feed which are found in considerable numbers.

19. *Mephitis putida* Boitard. Eastern Skunk.—This form was found to be quite plentiful. Farmers in the neighboring region report that skunks are at the present time somewhat troublesome to the poultry yards. Many tracks were found and also places where they had been digging around the roots of stumps, probably in search of grubs and insect larvae.

*33rd Ann. Rept. Dept. Geol. and Nat. Res., Ind. (1908), p. 550.

20. *Taxidea taxus* (Schreber). American Badger.—Farmers and hunters report that badgers are not rare in the Douglas Lake region. A farmer near Burt Lake had the skin of one in his possession. None were observed by the writer.

21. *Lutreola vison* (Schreber). Northeastern Mink.—Tracks of the mink were found in some abundance along the small stream which flows into North Fish-tail Bay. Hunters and trappers report that they are to be found in great numbers in the region of Negro Creek east of Burt Lake.

22. *Putorius noveboracensis*. Emmons. New York Weasel.—Weasel tracks were seen in the sand along the beach. Farmers report that they are troublesome to poultry.

23. *Procyon lotor* (Linnaeus). Common Raccoon.—These animals are probably still quite plentiful in the forest and timbered swamps of Cheboygan County where there are hollow trees large enough to afford them shelter. Tracks were plentiful along the shores of Douglas and Burt Lakes and the streams flowing into them.

24. *Ursus americanus* Pallas. Black Bear.—Occasionally a few bears make their appearance in any region in Northern Michigan where wild berries are abundant. One was seen between the lakes, during the summer of 1910, by men working in a small mill on Burt Lake. Farmers and hunters report that black bears are occasionally seen, but no one seemed able to say where they live or where they go when they leave. The writer was told by a farmer living about three miles east of Douglas Lake that a small child was killed and eaten by a bear a year or two ago, while its mother was picking berries. This hardly seems credible, especially in berry season, though it was apparently believed by the man who told it.

25. *Blarina brevicauda* (Say). Short-tailed Shrew.—This species was found in a piece of low almost swampy ground on the south side of North Fish-tail Bay.

Museum Number.	Sex.	Length.	Tail.	Foot.
41380	Adult male	115	21	15
	?	95	25	13

26. *Condylura cristata* (Linnaeus). Star-nosed Mole.—A specimen of the star-nosed mole was taken in the farming settlement southeast of Douglas Lake or east of Burt Lake.

Museum Number.	Sex.	Length	Tail.	Foot.
41377		190	82	27

27. *Myotis subulatus* (Say). Say's Brown Bat.—Many bats were seen about the station in the evenings, though it was found difficult to secure them. The only specimen taken was Say's bat.

Ann Arbor, Mich., April, 1911.

ODONATA COLLECTED AT DOUGLAS LAKE, MICHIGAN, IN THE SUMMER OF 1910.*

ABIGAIL O'BRIEN.

The Odonata in the following list were observed in the immediate vicinity of the University of Michigan Biological Station at Douglas Lake, Cheboygan County, Michigan, between July 9 and August 26. Thanks are due to Dr. A. S. Pearse, Assistant Director of the Station, for advice and assistance; to Mr. E. B. Williamson of Bluffton, Indiana, for valuable suggestions and the identification of the specimens of species numbers 8, 12 and 13, and the verification of the writers identification of specimens of species numbers 4, 16, 17, and 18, and to Mr. E. M. Walker, University of Toronto, for identification of the specimens of species numbers 20, 21 and 22.

1. *Enallagma carunculatum* Morse.—Very common throughout the whole time.

2. *Enallagma exsulans Hagen.*—Several taken, two in copulation.

3. *Ischnura verticalis Say.*—Two females and one male taken August 20.

4. *Lestes disjunctus* Selys.—First taken July 22, common till August 15.

5. *Lestes uncatus* Kirby.—Taken several times from July 23 till August 20.

6. *Lestes unguiculatus* Hagen. One male taken August 18.

7. *Lestes forcipatus Rambur.*—Several of both sexes taken August 19.

8. *Nehalennia irena* Hagen.—Taken July 23 and later until August 20.

9. *Sympetrum assimilatum* Uhler.—Male and female taken together, also other specimens, August 19.

10. *Sympetrum obtrusum* Hagen.—Taken from July 23 to August 20.

11. *Sympetrum rubicundulum* Say.—Common at several places around the lake from August 8 to August 15, rare after the latter date.

12. *Sympetrum costiferum* Hagen.—Common from August 1 to 15. Tarsi were black instead of yellow as given by Muttkowski (Bulletin Wisconsin Natural History Society (2) 6, page 111, (1908).

13. *Sympetrum scoticum Donovan.*—A few taken on August 11.

14. *Progomphus obscurus* Selys.—Four adults taken about the camp. Nymphs were very common in the sand along the lake shore under a few inches of water. Efforts were made to raise them from nymphs kept in receptacles near the laboratory, but they were unsuccessful. The species apparently has not been reported from as far north as Douglas Lake. The nymphs were common all summer but adults were not found after August 11.

* Contributions from the Zoological Laboratory of the University of Michigan, No. 134 (Biologica Station Series, Zoological Publication No. 4.

15. *Gomphus scudderi* Selys.—One male only; taken July 25.

16. *Gomphus ventricosus* Walsh.—One male only; taken July 21.

17. *Dromogomphus spinous* Selys.—Common everywhere all summer. Exuviae found in great numbers on the shore of Burt Lake, where they were seen emerging, June 21, by Dr. Pearse.

18. *Hagenius brevistylus* Selys.—Common everywhere all summer; often seen far out on the lake. One was seen to emerge from the nymphal skin on June 24 by Dr. Pearse.

19. *Boyeria vinosa* Say.—Several specimens of both sexes were taken and always in camp although Killicott says they prefer seclusion. July 30 to August 30.

20. *Anax junius* Drury.—A few nymphs of various ages were taken but no adults.

21. *Aeschna canadensis* Walker.—Six males and four females were taken and others seen, July 21 to August 20. One was seen August 20, laying eggs on the moist wood of the dock.

22. *Aeschna interrupta* Walker.—One taken, August 18.

23. *Macromia illinoiensis* Walsh.—One adult taken and a nymph found in the sand and scanty vegetation in eighteen inches of water. A single exuvia was found on the shore of Burt Lake.

Nymphs of the Zygoptera were found at various times but no effort was made to identify them.

April, 1911.

THE ORTHOPTERA COLLECTED AT DOUGLAS LAKE, MICHIGAN, IN 1910.*

ALVALYN E. WOODWARD.

All the Orthoptera collected at the University Biological Station in 1910 were given to the writer for identification. For aid in identifying five species I am indebted to Prof. H. Osborn, of the Ohio State University, and to Mr. A. N. Caudell, of the National Museum. Professor A. S. Pearse, acting director of the station, furnished thruout the summer inspiration and aid in many ways, without which the work could not have been done. The description and keys are introduced for the convenience of students at the station.

Of the books referred to in the work, the following were found of the greatest help:

Blatchley, W. S.—"The Orthoptera of Indiana." Annual Report Indiana Department of Geology, 1901-2.

Lugger, Otto—"The Orthoptera of Minnesota." Annual Report of Entomologist, University of Minnesota, 1897.

Hancock, Joseph L.—"The Tettigidea of North America." Chicago, 1902.

Saussure, Henri D.—"Podromus Oedipodiorum Insectorum ex ordine Orthoptorum." Memoir de la Societé de physique et d'historie naturelle de Genève, 1884.

Scudder, Samuel H.—"Revision of the Orthopteran Group Melanopli (Acrididae), with Special Reference to North America Forms." Proceedings U. S. National Museum, XX . Washington, 1897.

The Douglas Lake region is comparatively new country. There are small areas of virgin pine—hemlock forest, a few cleared farms, bogs of various ages, and, near the biological station, a great tract which was burned over about ten years ago, and which has grown up to poplars, birch, and brake fern. Near the lake is a bare beach. With the exception of the loam in the bogs, the soil of the whole region is pure sand. As would be expected, there is not the usual variety of vegetation, only about 250 species of flowering plants being represented. Both the plants and animals are hardy forms, usually characteristic of high altitudes or latitudes. The birds and insects occur in very large numbers, but the variety of species is not correspondingly large.

While an attempt was made to have the list of Orthoptera complete, the writer is not convinced that it is so, since five species not previously taken were collected during the last week of the season. Between July 4 and August 28, thirty species were found, distributed through eighteen genera and ten sub-families. *Camnula pellucida* was the most numerous species. *Dissosteira carolina* was probably second in abundance,

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but is so difficult to catch that it did not form a large proportion of any one day's catch. The two tables (I and II) represent the results of two typical day's collections.

Collected at Pine Point.

	Males.	*Females.*	*Total.*
Camnula pellucida	18	11	29
Dissosteira carolina	1	4	•
Melanoplus atlanis	1	......	5
bivittatus	5	3	8
femur-rubrum	6	1	7
Oecanthus fasciatus	1	2	3
Scudderia pistillata	2	....	2
Xiphidium fasciatum	12	14	26

Collected along Carp Creek Road, near Concrete Bridge.

	Males.	*Females.*	*Total.*
**Cammula pellucida*	3	1	4
Gryllus arenaceous		1	1
Melanoplus atlanis.	3	2	5
femur-rubrum	3	1	4
luridus	4	1	5
Oecanthus fasciatus	1	2	3
Xiphidium fasciatum	3	.	3

*Most of the *Cammula pellucida* caught were rejected and so not taken to the laboratory for count

The Orthoptera are grouped by Blatchley into the sub-orders—Non-saltatoria, those not adapted for jumping, and Saltatoria, the jumpers, with hind legs much thicker and longer than the middle pair.

NON-SALTATORIA.

To the Non-saltatoria belong four families, the ear-wigs, roaches, mantids, and walking-sticks. But one species of all of these, however, was found, a roach which was probably:

1. *Ischnoptera pennsylvanica* (De Geer).—"Male: Pronotum elliptic, front border slightly narrower, its margin straight; the hind border rounded; an oblique depression on each side, near the base. Tegmina membranaceous, more or less transparent, long and rather narrow, extending much beyond the tip of the abdomen; wings as long as tegmina. Sub-genital styles deflexed.

"Female: Abdomen broader than thorax, its greatest width contained less than twice in its total length. Disk of pronotum a little convex, and with no impressions; its hind margin nearly truncate, the front margin narrower, rounded; the lateral margins somewhat flaring, their posterior third slightly upturned. Tegmina broad, over-lapping, covering from a half to three-fourths of abdomen, their apices rounded; the veins prominent. Inner wings narrow, about half the length of the tegmina.

"General color, chestnut brown to fuscous, the females the darker. Face reddish brown in center, the margins yellow. Disk of pronotum

chestnut brown, margined on sides, and sometimes in front, with whitish yellow. Tegmina of male smoky brown; of female, dark reddish brown; the outer basal portion margined with yellowish.

"Measurements: Length of body, male, 21 mm., female, 16 mm.; of antennae, male, 28 mm., of female, 18 mm.; of pronotum, male and female, 5 mm.; of tegmina, male, 22 mm., female, 6-10 mm."—Blatchley.

These roaches were dug out of rotten logs in the latter part of July.

SALTATORIA.

Key to Families.

I. Antennae shorter than the body. Tarsi three-jointed. Ovipositor two pairs of short, curved, hard, diverging plates. *Acrididae.*

II. Antennae longer than the body. Tarsi three or four-jointed.
   1. Tarsi four-jointed. Tegmina with sides sloping. Ovipositor a flat, hard blade. *Locustidae.*
   2. Tarsi three-jointed. Tegmina flat above, sides abruptly bent. Ovipositor long and needle-like, tip sometimes enlarged. *Gryllidae.*

FAMILY ACRIDIIDAE.

The Acridiidae are characterised by short antennae, the presence of three ocelli, three joints in the tarsus, and auditory organs located on the basal segment of the abdomen. There is a great variety in the development of wings and tegmina, which in some species extend far beyond the end of the abdomen, in some barely reach the tip, in others are no longer than the pronotum, and in still others are entirely wanting.

Key to Sub-families of Acridiidae.

I. Pronotum extending to, or nearly to end of abdomen. *Tettigidae.*

II. Pronotum never covering first segment of abdomen.
   1. A spine on prosternum between front legs. *Acridiinae.*
   2. No spine on prosternum.
      a. Face very oblique, fastigium horizonal, median carina of pronotum low, with never more than one sulcus. *Tryxalinae.*
      b. Face nearly vertical, fastigium sloping downwards. *Oedipodinae.*

SUB-FAMILY TETTIGIDAE.

The Tettigidae or grouse locusts, our smallest Acrididae, vary in length from six to fifteen millimeters. They are easily distinguished from others in this family by the *very long pronotum,* which nearly or completely covers the abdomen, sometimes extending twice the length of the abdomen. It is the only sub-family the individuals of which live through the winter. The eggs are laid in the ground or among lichens

from April to early July, depending on the species and the climate, hatching in about three weeks. The color and markings of individuals are of little use in distinguishing species because there is so much variation within the species.

Dr. J. R. Hancock describes twenty-one genera, only five of which are found in north-eastern United States. Of these, three were found at Douglas Lake.

Key to Genera and Species of Tettigidae.

I. Anterior femora carinate above. Antennae 12-14 joints.
- 1. Dorsal front margin of pronotum truncate, not produced upon head beyond posterior margin of eyes.
  Genus, *Tettix*.
  - *a.* Eyes small, vertex about the width of one eye.
    2, *ornatus*.
  - *b.* Vertex about twice the width of one eye.
    3, *acadicus*.
- 2. Dorsal front margin of pronotum angulate, produced in front of posterior margin of eyes.
  Genus, *Nomotettix*.
  - *a.* Shallow fossa on each side of median carina of vertex. Face strongly retreating, body not over 7 mm. in length.
    4, *parvus*.
  - *b.* Deep fossa on each side of anterior part of median carina of vertex.
    - (*a*) Median carina of pronotum strongly compressed, translucent, punctate.
      5, *compressus*.
    - (*b*) Median carina of pronotum low, only slightly arched.
      6, *cristatus*.
    - (*c*) Pronotum strongly arched and strongly advanced upon head.
      7, *arcuatus*.

II. Anterior femora sulcate above. Antennae 16-22 joints.
- 1. Lateral carinae present in front of shoulders. Distribution United States.
  Genus, *Tettigidea*.
  - *a.* Antero-dorsal margin of pronotum obtuse, vertex decidedly wider than one of the eyes, wings and pronotum extending beyond posterior femora.
    8, *parvipennis pennata*.

Genus Tettix Charpentier.

Dr. Hancock, who describes twelve species and as many more varieties, says: "The tendency to vary is inherent in all the forms, the line of demarkation not easily drawn between species. * * * The descriptions of the species give a composite conception to the mind, the variations being of such wide range as to baffle separate description of each individual phase."

2. *Tettix ornatus* (Harris).—Vertex about the width of one eye; anterior margin obtuse; median carina projecting like a tiny tooth, extending beyond the eye about two-thirds the length of the eye; median carina only half the length of the vertex. Pronotum anteriorly truncate or slightly convex; narrow at anterior carinae, between two and three times as wide at shoulders; median carina strongly compressed, nearly straight. Anterior lateral sinus (near base of second femur) deep, scarcely separated from posterior sinus by a very shallow median lobe.

Measurements:—length of body, 8 mm.; pronotum, 7 mm.; hind femora, 5 mm.

Tettix ornatus is the most common of the Tettigidae, and shows great variation in markings. The pronotum is commonly either fuscous with velvety black spots, or gray with white spots and dark lines.

3. *Tettix acadicus* (Scudder).—Vertex about twice the width of one eye; anterior margin truncate, extending only slightly beyond eyes; median carina projecting, indistinct posteriorly; profile of face showing indentation just below lower border of eyes. Pronotum truncate anteriorly, acute posteriorly; shoulders three times the width of the space between the anterior carinae. Median carina of pronotum low, slightly arched, highest just in front of shoulders. Lateral lobe truncate posteriorly, median lobe very small.

Measurements:—length of body, 6.5 mm.; pronotum, 5.7 mm.; hind femora, 4.5 mm.

Genus Nomotettix Morse.

This genus seems to be well represented at Douglas Lake; of Hancock's eight species, four are found. Besides the characteristic given in the key, it differs from Tettix in having, commonly, a pair of rounded protuberances between the eyes and the median part of the pronotum.

4. *Nomotettix parvus* Morse.—Vertex one and one-half times the width of an eye; anterior margin obtuse-angled (about 150°); extending in front of the eyes one-half the length of an eye; median carina on anterior third of vertex, followed by a shallow groove, which widens posteriorly. Profile shows two indentations, a very shallow one above the ocellus, and a deeper and longer one half way from the vertex to the clypeus. Pronotum reaches to knees; anterior margin roundly obtuse, posterior margin acuminate; anterior carinae start at about the middle of the eye and somewhat approach each other; shoulders widen posteriorly. Median carina slightly arched before shoulders. Posterior lateral sinus deep, acute angled; anterior sinus shallow.

Color:—vertex, dark fuscous punctuate and bordered with yellow. Eyes black streaked with chestnut. Pronotum and legs tawny marked with black; finely punctate.

Measurements:—length of body, 6.5 mm.; pronotum, 6.75 mm.; hind femora, 5 mm.

5. *Nomotettix compressus* Morse.—Body slender, compressed. Vertex twice the width of an eye, flaring toward front; anterior margin obtuse-angled (about 120°); vertex twice as long as wide; median carina two-thirds its length. Profile shows sharp and deep indentation above ocellus, making the vertex appear, from the side, very acute. Pronotum

truncate anteriorly, acute posteriorly. Median carina strongly keeled, with fine indentations, sometimes puncturing it near the edge; punctations usually arranged in one or two rows. Pronotum does not reach to knees. Wings abbreviate.

Color:—Vertex dark reddish brown, marked with black. Face black or fuscous. Dorsal part of pronotum yellowish brown, lateral part darker. Legs yellowish brown, with bands of darker red-brown on both femora and tibiae.

Measurements:—Length of body, 6.5 mm.; pronotum, 5.5 mm.; hind femora, 4 mm.

There is also a form with pronotum and wings extending beyond the hind femora, but it was not found at Douglas Lake.

6. *Nomotettix cristatus* Morse.—Vertex not over one and one-half times the width of one eye, sides parallel, front margin rounded, with median carina projecting. Profile rounded. Pronotum advanced to front third of eye; anterior margin right-angled; anterior carinae parallel; median carina low, slightly arched in front of shoulders. Anterior lateral lobe acute, posterior very small, rounded; anterior lateral sinus deep, acute, posterior sinus shallow. Pronotum reaches to knees.

Color:—Fuscous, with a black spot on each shoulder, and blackish rings on legs.

Measurements:—Length of body, 7.25 mm.; pronotum, 6.75 mm.; hind femora, 4.5 mm.

7. *Nomotettix arcuatus* Hancock.— This species has the stoutest body of all the Tettigidae found. Vertex narrow; front margin truncate; median carina projecting like a tooth, fossa on each side; eyes not projecting as much as in other species. Profile with one shallow indentation below lower border of eyes. Pronotum acute or right-angled anteriorly, extending nearly to front margin of eye; between the anterior carinae the pronotum is twice the width of the vertex; median carina strongly arched; does not extend to tip of abdomen; lateral sinus very shallow. Wings sometimes longer than pronotum, sometimes abbreviate.

Color:—Dark reddish brown. There were no markings on my specimen.

Measurements:—Length of body, 7.5 mm.; pronotum, 5.5 mm.; hind femora, 4 mm.

Genus Tettigidea Scudder.

The members of this genus have stouter, more clumsy bodies, and larger heads, with less oblique faces than others of the Tettigidae. The dorsal surface of the pronotum is usually finely granulate or rugose; its sides slope downward between the shoulders. The males are more slender than the females, and there is much variation in the length of the wings.

8. *Tettigidea parvipennis pennata* (Harris).—Vertex wider than one of the eyes, truncate anteriorly, with median carina projecting. Profile nearly vertical, gently rounded. Pronotum obtuse on anterior margin; lateral and anterior carinae united; surface rugose. Median carina compressed, arched at shoulders and at anus; lateral lobe nearly right-angled; lateral sinus deep.

Color:—Fuscous, excepting for a tawny streak on dorsal surface of pronotum on each side of the median carina; legs with brown rings.

Measurements:—Length of body, 10 mm.; pronotum, 8.75 mm.; hind femora, 4 mm.

Tettigidea parvipennis is a species similar to this, but with wings and pronotum shorter than the hind femora.

SUB-FAMILY ACRIDIINAE.

This sub-family called Acridiinae by Blatchley, 1902, corresponds to Scudder's Melanopli, 1898. I prefer Blatchley's name, not only because it is later, but also because there is a large genus Melanoplus in this sub-family. It seems confusing to have two applications of the same term.

As the key indicates, the easiest way to distinguish the Acridinae is by the presence of a bluntly conical spine on the prosternum. The pronotum is nearly smooth, the median carina low, not deeply cut by the transverse sulci, lateral carinae rounded or wanting, and the head is not so large that the pronotum needs to flare to receive it. The wings are never brightly colored or marked.

Professor Scudder describes 30 genera, one of which contains 136 species. Blatchley reported six genera and 26 species from Indiana. The two genera and six species found at Douglas Lake may be distinguished by the following:

Key to Genera and Species of Acridiinae.

I. Tegmina and wings wanting.

9, *Podisma variegatus.*

II. Tegmina and wings present.

Genus *Melanoplus.*

1. Cerci of male no wider beyond the middle than at the middle.
    - *a.* Apex of sub-genital plate of male with median notch. Hind femora with dark cross-bars on outer surface.

      10, *atlanis.*
    - *b.* No apical notch on subgenital plate of male. Hind femora without dark crossbars on outer surface.

      11 *femur-rubrum.*
2. Cerci of male broader at some point beyond middle than at middle.
    - *a.* Male less than 20 mm. in length. Cerci with forks of equal size.

      12, *luridus.*
    - *b.* Male more than 20 mm. in length. Cerci spatulate, not forked.
        - (a) Pronotum with dark stripes. Hind tibiae yellow.

          13, *differentialis.*
        - (*b*) Pronotum with light lateral stripes. Hind tibiae red or purple.

          14, *bivitattus.*

Genus Podisma Lutreille.

Scudder says: "This genus is more widely extended than any other of the Melanopli [Acridiinae], being the only one not confined to America. It is a distinctly boreal type and encircles the globe. The species are confined to high altitudes as well as high latitudes, a number being alpine or sub-alpine in their respective localities." They are found in Siberia and Japan, as well as in the mountains of southern and eastern Europe.

In Podisma, the tegmina are never well developed, and are often entirely wanting. The pronotum has not very distinct sulci or carinae; it is either the same width throughout or larger posteriorly, never constricted in the middle.

9. *Podisma variegata* Scudder.—The vertex sloping downward, narrower than the eye; median carina not distinct. Frontal costa narrower than space between eyes, sulcate; foveolae not distinctly marked off, trapezoid. Antennae filiform, as long as or longer than hind femora. Pronotum sub-cylindrical, flaring gradually towards back; both anterior and posterior margins truncate; median carina low but distinct; lateral carinae wanting; prozona nearly twice the length of the metazona. Tegmina and wings wanting. Hind femora slender, reaching to tip of abdomen, but not to tip of ovipositor in the female. Sub-genital plate in male with a distinct sub-apical tubercle; furcula no longer than wide; cerci projecting dorsally, considerably above the supra-anal plate; narrowing sharply to middle, then slightly enlarging, the tip about half the width of the base, somewhat flattened.

Color:—General color olive green; face puncate with yellow; disk of pronotum green; a chocolate streak from the eye along the head, pronotum, meso- and meta-notum, below this, bright pinkish yellow. In the male there is a distinct red-yellow streak along the mid-dorsal line of the thorax and abdomen. The abdomen is green tinged with dark red, somewhat yellowish underneath. The hind femora are green, with three yellowish cross bars; the knees fuscous; the tibiae green, becoming reddish at the apical end.

Measurements:—Length of body, male, 19 mm., female, 22 mm.; pronotum, male, 3.5 mm.; hind femora, male, 10 mm., female, 12 mm.; antennae, 12 mm.

Genus Melanoplus Stal.

To this genus belong 136 or more species, a greater number than is in any other genus of Saltatoria. They are also the most commonly found group in the northern United States. The infamous Rocky Mountain Locust is in this genus.

"Body moderately stout; generally feebly compressed. Head not prominent, but little if any longer than prozona. Face almost vertical. Disk of pronotum usually only half as long again as the average breadth; the prozona distinctly longer than the metazona, its edges parallel, its surface a little convex and faintly punctate; metazona with its edges more or less diverging backward, its surface flat and densely punctate; lateral lobes of pronotum vertical or nearly so, and usually marked on their upper half with a black band. * * * Cerci of male exceedingly variable in form. * * * Furcula usually developed and

to a variable extent and also variable in form; so that they and the cerci furnish characters much used in separating the species from one another. * * * The tyro will probably have much difficulty in separating the females of the different species."—Blatchley.

10. *Melanoplus atlanis* (Riley).—Vertex about the width of the basal joint of antennae; sulcate; continuous with frontal costa, which is sulcate at the ocellus only, and widens ventrally; foveolae triangular. Antennae compressed in the basal third, longer than head and pronotum. Margin of pronotum rounded or truncate anteriorly, obtuse-angled or rounded posteriorly; median carina much more distinct on metazona than on prozona; lateral carinae distinct; prozona about the same length as the metazona. Tegmina narrow, longer than the abdomen. Hind femora stout, slightly shorter than the abdomen. Sub-genital plate of male with a median apical notch. Length of furcula about three times their average width. Cerci narrowing slightly from base to extremity, sub-spatulate.

General color, dull brown. Face yellowish; occiput nearly black; pronotum fuscous, with a black stripe on the lateral lobe back from the eye. Tegmina transparent, with fuscous veins, and small fuscous spots, usually arranged in a row from the shoulder to the tip. The ventral side of the abdomen of the male yellow, of the female, yellow sprinkled with fine fuscous dots. Hind femora yellow on inner face; outer face yellow with three faint fuscous bars; knees black; tibiae red, at least on apical third, spines black.

Measurements:—Length of body, male, 20 mm., female, 23 mm.; tegmina, male and female, 20 mm.; hind femora, male, 12 mm., female, 13.5 mm.

11. *Melanoplus femur-rubrum* (De Geer).—Occiput indistinctly carinate; vertex deeply sulcate, distinctly separated from the frontal costa, which has parallel sides and is sulcate only below the ocellus. Foveolae lacking. Antennae flattened in the basal third. Pronotum truncate anteriorly, rounded or obtuse posteriorly, carinate throughout, but more distinctly on the metazona; only the last of the three sulci cuts the median carina, making the prozona and metazona the same length; lateral carinae straight, distinct; lateral lobes of prozona smooth, of metazona, finely and densely punctate. Tegmina of the female reach to or slightly beyond the tip of the abdomen; in the male they extend one-fourth of their length beyond the abdomen. The hind femora do not quite reach the tip of the tegmina in either sex. Furcula of male three times as long as wide at the base, curved from the base outward, and then inward, and placed in grooves of the supra-genital plate. Cerci only half as wide at the middle as at the base, tapering to the end, curved inward. Sub-genital plate pilose.

General color, olive brown; face yellowish or greenish, occiput oliveo-fuscous; disk of pronotum red-brown, lateral lobes the color of the face, with a black stripe from the eye across the prozona. Tegmina wood brown with very small fuscous dots. Hind femora yellowish brown, shading, on the lower border, to reddish; four black cross-bars on the upper inner surface; the outer surface immaculate; tibiae red, spines black.

Measurements:—Length of body, male, 18 mm., female, 25 mm.; teg-

mina, male, 16 mm., female, 19 mm.; hind femora, male, 11 mm., female, 14 mm.

12. *Melanoplus luridus* (Dodge).—Occiput, especially of male, swollen, so as to project above pronotum; space between eyes little if any wider than basal joint of antenna; vertex broadly and shallowly sulcate; frontal costa shallowly sulcate in male, plane in female; foveolae small, triangular. Pronotum anteriorly truncate, posteriorly obtuse-angulate; median and lateral carinae more distinct on metazona than on prozona; the prozona longer than metazona; surface pilose. Tegmina narrow, tapering, just short of tip of abdomen in female, reaching just beyond in male. In both sexes, the hind femora reach to the tip of the tegmina. Male furcula abbreviate, mere notches. Male cerci taper to the middle, then broaden; distinctly forked at tip, the lower prong being more slender than the upper one.

Color:—General color, wood brown; face bluish brown; occiput bluish black, bordered on each side by a yellowish line; disk of pronotum light brown on the sides, dark in the center; lateral lobes of pronotum with a black band across the top, light yellowish brown below. Tegmina dark brown, with or without small fuscous dots. Hind femora red-brown; three faint fuscous bars on upper surface; under surface yellow; knees black; tibiae bright red with black spines.

Measurements:—Length of body, male, 19 mm., female, 21 mm.; tegmina, male, 13.5 mm., female, 14.5 mm.; hind femora, male, 10.3 mm., female, 13 mm.

13. *Melanoplus differentialis* (Uhler).—No adults of this species were found. The larvae were found throughout the season; those caught on August 20, apparently in their last moult, were kindly identified for me by Professor Osborn. These are described instead of the adults.

Occiput somewhat swollen; vertex broad, slightly sulcate, continuous with the long and shallowly sulcate frontal costa; foveolae small, flat, equilateral triangles; antennae flattened in basal third. Pronotum truncate anteriorly, broadly obtuse posteriorly; disk somewhat sloping, lateral carinae not present; posterior border of lateral lobes oblique. Abdomen strongly compressed. Hind femora stout.

Color:—General color, bright green. Face green, dotted with brown, especially along the sides of the frontal costa; antennae green at base, becoming fuscous at tip. Pronotum with a brown stripe in the position for the lateral carinae. Abdomen with a red or brown band on the mid-dorsal surface. Hind femora green, with a longitudinal brown stripe on the outer surface; knees dusky; tibiae green with black spines.

14. *Melanoplus bivitattus* (Say).—There are great differences in every respect but color, between the male and female of this species. The width of the vertex and frontal costa of the female is more, of the male, less than twice the width of the basal joint of the antenna; vertex carinate in the male; frontal costa not distinctly sulcate. Foveolae indistinct, triangular. Pronotum truncate anteriorly, rounded posteriorly; median and lateral carinae distinct. Prozona longer than the punctate metazona. Tegmina of the female do not reach the tip of the abdomen, in the male they project one-fourth their length. Hind femora of the female reach the tip of the tegmina, in the male, they are shorter; stout in both sexes. Male furcula wanting; cerci narrow

slightly from the base to the middle, then widen slightly; truncate at the end.

Color:—There are two groups of *M. bivitattus,* those whose light parts are of a bluish cast, and those of an olive or yellow cast. Occiput fuscous, becoming lighter on the vertex and still lighter on the lower part of the face. Disk of pronotum fuscous, black line from eye along lateral lobe of prozona, the rest of the lateral lobe like the face. Light bluish or greenish yellow stripe from the upper angle of the eye, backwards, across the head, along the lateral carina of the pronotum, and humeral angle of the tegmina. General color of the tegmina oliveo or reddish-fuscous. Inner surface of hind femora yellow, four black bars near upper carina; outer surface fuscous above, light yellow below. Tibiae red.

Measurements:—Length of body, male, 26 mm., female, 39 mm.; antennae, male, 15 mm., female, 12 mm.; pronotum, male, 6 mm., female, 7.5 mm.; tegmina, male and female, 23 mm.; hind femora, male, 14 mm., female, 17 mm.

SUB-FAMILY TRYXALINAE.

The members of this group are characterized by a straight, horizontal or ascending vertex, a face which is very oblique, and often meets the vertex at an acute angle; the antennae are very variable, sometimes conical; the length of the tegmina often varies within the species. The disk of the pronotum is flat, with a low median carina, cut by but one sulcus. The wings and tegmina are transparent or dull colored.

But one genus and one species was found at Douglas Lake.

Genus Stenobothrus Fischer.

"Vertex triangular, obtuse in female, acute in male; the foveolae visible from above as narrow, oblong, or linear impressions; the median carina absent, or at most a colored line. Antennae filiform; much longer than head and pronotum in male. Pronotum with the median carina distinct, cut a little behind the middle by the principal sulcus; the lateral carinae sinuate or curved, so that the middle of disk is narnower than the fore and hind margins. Lateral lobes of pronotum about as long as deep, the front margin straight, the hind and lower margins sinuate. * * * Hind femora rather slender; not transversely barred. Valves of ovipositor short, but plainly exserted."—Blatchley.

15. *Stenobothrus curtipennis* (Harris).—Vertex narrow, rounded where it meets the face. Frontal costa narrow, oblique, sulcate at and below the ocellus. Antennae flattened throughout. Pronotum truncate or subtruncate both anteriorly and posteriorly. Median carina low but distinct, not crested, cut by the principal sulcus, which also cuts the lateral carinae. Length of tegmina varies from two-thirds to five fourths the length of the abdomen. Body slender. Male cerci straight, slender processes.

Color:—Face light brown, sometimes with the frontal costa dark. There is a light brown stripe along the median line of the vertex and pronotum, sometimes extending along the dorsal region of the tegmina. On the head and pronotum this stripe is bordered by a fuscous line, below which is another light, then another dark band. Tegmina light

brown, immaculate. Hind femora light brown, with a longitudinal fuscous band; knees black, tibiae brown. While the above markings are constant, *green* may be substituted for brown.

Measurements:—Length of body, male, 15 mm., female *a* 20 mm., female *b*, 21 mm.; tegmina, male, 11.5 mm., female *a*, 16 mm., female *b*, 11 mm.; hind femora, male, 11 mm., females, 13 mm.; antennae, male, 9 mm.

SUB-FAMILY OEDIPODINAE.

This sub-family is characterized by a rounded vertex, nearly vertical face, and the lack of a spine on the prosternum. The hind margin of the pronotum is wider than the front. They frequently fly twenty-five feet, or farther, and, since the inner wings are usually brightly colored, a careless observer may at first mistake them for butterflies.

The following table was intended to enable one to distinguish easily the Douglas Lake species, not to give true generic characteristics.

Key to Genera and Species of Oedipodinae.

I. Inner wings transparent at base; no distinct black border.
 16, *Camnula pellucida.*

II. Inner wings colored at base.
 1. Median carina cut by two sulci.
  17, *Circotettix verruculatus.*
 2. Median carina cut by one sulcus.
  a. Base of wings yellow.
   (*a*) Length of body less than 20 mm.; prozona one-half metazona.
    18, *Scirtettica marmoratus.*
   (*b*) Length of body more than 20 mm.; prozona more than one-half metazona.
    19, *Spharagemon bolli.*
  b. Base of wings red.
    20, *Arphia pseudonictana.*
  c. Base of wings black.
    21, *Dissosteira carolina.*

Genus Camnula Stal.

"Body short, the size below the average for *Oedipodinae*, the head compressed. Vertex with its disk ovate-oblong in male, broader in female, its front half sloping downward, the apex rounded, the lateral carinae distinct, the median carina very faint in the female, absent in the male; foveolae indistinct, narrowly triangular. * * * Antennae short, filiform. Pronotum with its disk flat, not rugose, * * * the lateral carinae distinct on both prozona and metazona. * * * Tegmina narrow, surpassing the abdomen; the apical third remotely reticulate, the cells quadrate. Inner wings pellucid with dusky venules."—Blatchley.

16. *Camnula pellucida* (Scudder).—Vertex tapering, carinate; frontal costa, at the top, about the width of the basal joint of the antennae, wider near the ocellus, shallowly sulcate, deepest at ocellus.

Pronotum truncate anteriorly, obtuse to right angled posteriorly; median carina low, cristate, not arched, faintly cut by principal sulcus; metazona one and one-half times the length of prozona, densely punctate. Male furcula wanting; cerci curved, tapering horns; abdomen strongly recurved. Ovipositor usually strongly exserted.

This species was the most numerous and most widely distributed of all found. Hence, since the colors harmonize with the surroundings, a great variety of ground colors—yellow, green, brown, dark gray—was found, always, however, with the following fuscous markings:—a v on the occiput; a line from the hind border of the eye, across the lateral lobe of the prozona; three diagonal crossbars on the outer face of the hind femora; knees; large splotches on the tegmina; a more or less distinct ring on the second quarter of the hind tibiae. The veins of the basal part of the wing are also fuscous.

Measurements:—Length of body, male, 16-21 mm., female, 21-23 mm.; tegmina, male, 15-18 mm., female, 20 mm.; hind femora, male, 11-13 mm., female, 13 mm.

Genus Circotettix.

"Body pubescent, punctate. Vertex nearly flat, ovate, slightly carinate, apex notched; frontal costa rather wide, sulcate, punctate at and above the ocellus. Pronotum strongly constricted near the principal sulcus; metazona almost twice the length of the prozona, flat, hind margin right or acute angled; lateral carinae acute anteriorly, obsolete posteriorly. The prozona has a small oblique ridge on each side, near the front margin. Median carina, in the prozona, narrow, low crested or tectiform, somewhat deeply cut, usually twice; in the metazona, cristate anteriorly, sub-obsolete posteriorly. Apical third of tegmina irregularly reticulate. Wings widely reticulate, for the most part, broad, the posterior margin strongly arcuate, the outer margin not strongly but regularly lobate;—or, posterior less arcuate, outer margin slightly doubly lobulate. Hind femora compressed, rather short and broad."—Saussure, translated by the writer.

17. *Circotettix verruculatus* Kirby.—Vertex a long oval, making, as seen from the side, almost a right angle with the face; foveolae triangular; antennae short, flattened. Pronotum with two distinct sulci cutting the median carina in front of the middle, the first notch broad, the second narrow and oblique; front margin truncate, hind margin acute. Tegmina narrow, extending about one-third their length beyond the abdomen. Hind femora barely reach the tip of the abdomen.

Color:—Gray, with many fuscous splotches. Face mainly gray. Pronotum black. Tegmina dark fuscous at base, lighter in the apical half, with small fuscous dots. Wings sulphureous at the base; a fuscous band begins near the anal angle and curves across to the middle of the outer margin, just within which a narrow dark ray goes towards the base of the wing; apex fuscous; between the apex and the dark band is a transparent area, with dark veins. Hind femora dark on the outer surface, with three gray or yellowish crossbars; tibiae have two light and two dark bands; tarsi light.

Measurements:—Length of body, 23 mm.; tegmina, 26 mm.; hind femora, 12 mm.

Genus Scirtettica Saussure.

"Scutellum of the vertex longer than broad, the bounding walls moderate, median carina absent or lightly developed; frontal costa sulcate, broadening and shallow below. Pronotum constricted anteriorly, the median carina distinct but low, distinctly cut by the principal transverse sulcus and often with a second more or less indistinct incision. Elytra slender, except in *occidentalis*, the intercalary vein nearer the median than the ulnar vein, apically nearly or quite touching the former; wings with a distinct black band immediately beyond the middle, subobsolete in *occidentalis*, the base yellowish or orange. Hind femora moderately heavy, marked on both faces and above with black bars; hind tibiae reddish or yellowish."—Mr. A N. Caudell.

18. *Scirtettica marmoratus* Harr.—Vertex deeply sulcate, no median carina; foveolae small, deep, equilateral triangles; frontal costa about the width of the basal joint of antenna, deeply sulcate. Anterior border of pronotum obtuse or sub-truncate, posterior border right-angled; median carina higher on prozona than on metazona, deeply cut by principal sulcus, *very slightly* notched by secondary sulcus; lateral carinae distinct on metazona only. Tegmina one and one-half times length of abdomen. Hind femora reach tip of abdomen.

Color:—Head, dark reddish brown to fuscous; disk of pronotum has x-shaped mark of gray or brown on a fuscous ground, sides gray or brown with fuscous blotches. Tegmina gray, irregularly spotted with black,—black at tips. Wings pale yellow at base, middle third crossed by a broad fuscous band which begins at the anal angle; beyond this is a transparent band in which the veins are fuscous; tip fuscous; hind femora gray with three fuscous bands; inner surface yellowish, three black bands; tibiae successively fuscous, white, fuscous, red, black. Spines with black tips.

Measurements:—Length of body, 18 mm.; tegmina, 19 mm.; hind femora, 10 mm.

Genus Spharagemon Scudder.

"Body slender, more or less compressed. Head rather swollen above, * * * the foveolae wide and distinct. Frontal costa narrow, sulcate, at least below the ocellus. Antennae in both sexes about as long as hind femora; filiform, the joints of the basal third a little flattened. Pronotum with the disk of metazona flat, that of prozona with the sides sloping; the median carina high and strongly compressed, cut a little in front of the middle by a deep but narrow notch. Inner wings yellow with dark curved median band. Hind femora rather short and stout, equalling, or a little exceeding, the tip of the abdomen. Hind tibiae, in our species, with at least the apical half red. Valves of ovipositor short; but little exserted.

"This genus is clearly related to *Dissosteira*, and Saussure, in his Podromus, has placed it as a sub-genus under that one. Eight species are known from the United States."—Blatchley. But one species was found at Douglas Lake.

19. *Spharagemon bolli* Scudder.—Disk of vertex broad posteriorly, narrow anteriorly, carinate; frontal costa convex above ocellus, sulcate below; foveolae distinct, triangular. Pronotum but slightly enlarged

to receive head; hind margin right or obtuse angled; surface of prozona slightly, of metazona closely, papillate. Tegmina much longer than abdomen.

Color:—General color, reddish brown. Face light brown, occiput and disk of pronotum fuscous. Tegmina yellowish brown sprinkled with fuscous, usually three fuscous crossbars. Wings yellow at base, with broad curved band of black from the middle of the outer border to a point just short of the anal angle; beyond dark band is a dusky transparent region; apex frequently fuscous.

Measurements:—Length of body, 21 mm.; tegmina, 24 mm.; hind femora, 14 mm.

Genus Arphia Stal.

"Body compressed, glabrous. Pronotum granulate, median carina sometimes sulcate, sometimes entire. Tegmina of one color, very densely reticulate, apex quadrate-areolate, sometimes pellucid; the whole with minute dark dots, or many larger dark blotches, never with crossbars. Wings with a broad dark band on the hind margin, from which a stripe runs, on the outer edge, towards the base. Median vein frequently united with the discoidal. Hind femora stout, margins carinate, inner surface black with two yellow stripes. Hind tibiae blue, yellow at base (in dried specimens fuscous in the basal half, or if faded, with fuscous rings). Arolia between the claws of the tarsus minute or lobiform.

"The species usually have a granulate pronotum and variously colored wings.

"The species which form a part of this genus are very similar to one another, and as they vary much, sometimes in the form of the frontal costa, sometimes in the color of the wings which pass readily from red to yellow orange, they are very difficult to distinguish, and still more, to describe."—Saussure.

20. *Arphia pseudonietana* Thomas.—Vertex with marked median and lateral carinae, distinctly separated from the frontal costa, which is flat, slightly sulcate at ocellus. Foveolae large, oblong. Pronotum slightly angulate on front margin, acute posteriorly; median carina cut once, in front of middle; lateral carinae more distinct on metazona than on prozona. Tegmina surpass abdomen in both sexes.

Color:—General color almost black. Face grayish. Tegmina with fuscous bars across the black and usually a red or tawny stripe along the median border. Wings red or orange at base. Hind femora black, with yellowish white ring near knee. The hind tibiae black, white ring in upper fourth.

Measurements:—Length of body, male, 22 mm., female, 26 mm.; tegmina, male, 22 mm., female, 21 mm.; hind femora, 14 mm.

Genus Dissosteira Scudder.

"Vertex with the disk sub-pentagonal or ovate; the front half a little downward sloping, its front margin angulate; the lateral carinae low; the median carina present but indistinct; the foveolae short, triangular. Frontal costa sulcate, a little narrowed below the ocellus. Pronotum with disk of prozona sloping, that of metazona flat; front margin truncate, hind margin obtuse or right angled; the median carina high and

sharp, and on the metazona strongly arched, cut in front of the middle by a deep but narrow notch; lateral carinae rounded, cut by the principal sulcus and obsolete in front of it. Lateral lobes of pronotum deeper than long, the front margin vertical, the hind margin oblique. Tegmina broad, much exceeding the abdomen; the whole of apical third membranaceous. Inner wings long and wide, black, with a narrow yellow outer border; the apex fuscous."—Blatchley.

21. *Dissosteira carolina* (Linnaeus).—The shape is described in the account of the genus.

Color:—There is a wide variation in color, from light gray through browns and reds to fuscous; also the body and tegmina may be almost entirely without dots or marks of any kind, or may be thickly covered with dark dots or spots. The inner surface of the hind femora always has three black bars, separated by yellowish white; the apical third of the tegmina is translucent; the inner wings are black, with a narrow yellow border, which is darkened at the apex by small fuscous spots.

Measurements:—Length of body, male, 26 mm., female, 38 mm.; tegmina, male, 31 mm., female, 40 mm.; pronotum, male, 6 mm., female, 9 mm.; hind femora, male, 13 mm., female, 17 mm.

Nymphs were found all through July.

FAMILY LOCUSTIDAE.

"This family comprises those insects commonly called katydids, green or long-horned grasshoppers, and stone or camel crickets.

"The distinguishing characteristics of the members of the family are the long, slender, tapering, many-jointed antennae; the almost universal absence of ocelli or simple eyes; the four-jointed tarsi (excepting in the genus *Daihinia*); and the sword-shaped or falcate ovipositor of the females, which is made of four flattened plates. The head in many of the species is wedge-shaped, and the mouth-parts are well developed, the mandibles especially being long and sharp-pointed. * * * The tegmina, or wing covers, when present, slope obliquely downwards, instead of being bent abruptly, as in the Gryllidae, or true crickets; and in most cases, the wings are longer than the tegmina.

"The stridulating or musical organ of the males is quite similar in structure to that of the male cricket, being found at the base of the overlapping dorsal area of the tegmina and usually consisting of a transparent membrane, of a more or less rounded form, which is crossed by a prominent curved vein, which, on the under side, bears a single row of minute, file-like teeth. In stridulating, the wing covers are moved apart and then shuffled together again, when these teeth are rubbed over a vein on the upper surface of the other wing cover, producing the familiar sound. * * * The ear of these insects, when present, is also similar in structure and position to that of the cricket's, being an oblong or oval cavity covered with a transparent or whitish membrane, and situated on the front leg, near the basal end of the tibiae."—Blatchley.

Key to Genera and Species of Locustidae.

I. Tegmina and wings absent; pronotum not covering the rest of the thorax, ovipositor nearly straight, eyes nearly round.
Genus *Ceuthophilus.*
  1. Hind femora of male 10—13 very small, unequal spines, on outer lower carina.
  22, *maculatus.*
  2. Hind femora of male having, on outer lower carina, 8-12 very unequal spines, some of which are conspicuous hooks.
  23, *latens.*

II. Tegmina and wings present.
  1. Vertex rounded or deflexed; hind tibiae with apical spine on each side; tegmina of nearly equal breadth throughout; superanal plate of male with long downward curving spine.
  Genus *Scudderia.*
    a. Notch of supra-anal spine of male acute; hind tibiae green.
    24, *Pistillata.*
    b. Notch of supra-anal spine of male round; hind tibiae red.
    25, *furcata.*
  2. Vertex produced slightly upward to form a tubercle; no apical spine on hind tibiae; fore and middle femora without spines beneath; ovipositor nearly or quite straight.
  Genus *Xiphidium.*
    a. Ovipositor shorter than the slender body; wings and tegmina longer than abdomen.
    26, *fasciatum.*

Genus Ceuthophilus Scudder.

These "wood crickets" or "camel crickets" are wingless, with the back curved, and with the head carried downward between the front legs. The vertex curves downward, and there are no grooves or ridges on the head, so that, excepting for the bright eyes, the face is quite characterless. The antennae are very long, slender, and tapering. The ovipositor is nearly straight, with only the tip slightly turned up.

The members of this genus live in caves, or spend the day under stones and rotten logs. Our two species were found under logs.

22. *Ceuthophilus maculatus* (Say).—The fore femora are quite unarmed; the middle have two very small spines on the lower margin; and the hind ones have about twelve very small nearly equal spines on the lower outer margin in the male.

Color:—General color sooty brown. On the thorax there is often a yellow median line, and on the abdomen there are numerous small yellow spots, often arranged in transverse rows. Hind femora are light reddish brown or yellow, with very small darker cross bars arranged in rows.

Measurements:—Length of body, 12 mm.; prothorax, 3.75 mm.; front femora, 5.5 mm.; hind femora, 12 mm.; antennae, 38 mm.

23. *Ceuthophilus latens* Scudder.—The front femora, in this species, have from one to three spines; the middle femora, four or five; and in the male the hind ones have, on the outer carina three to five very large conspicuous spines interspersed among smaller ones; the inner carina of the male and both carinae of the female have 10-15 small, nearly equal spines.

Color:—In general, light yellowish brown; on each side of the back is a fuscous band, bordered by yellowish brown; on the abdomen, and sometimes on the meso- and meta-notum this band is dotted with yellow. Legs yellow; small dark spots, usually arranged in rows, on the hind femora. Knees fuscous.

Measurements:—Length of body, 20 mm.; pronotum, 5.5 mm.; front femora, 8 mm.; hind femora, 17 mm.; antennae, 52 mm.; ovipositor, 11 mm.; cerci, 5 mm.

Genus Scudderia Stal.

This is the only one of the four or more genera of katydids, which was found at the station. It can be distinguished from the other genera by the very narrow, almost acuminate vertex, and by the peculiar spine curving downward from the supra-anal plate of the male, to touch a similar spine curving upward from the sub-anal plate. The ovipositor is a short, broad, upward curving blade, finely toothed near the end. The hind femora have a few very small spines on the lower outer carina, while the other femora are unarmed. The hind legs are very long and slender, reaching nearly to the tip of the wing-covers.

24. *Scudderia pistillata* Brunner.—The general color is bright green, with round black eyes and fuscous feet. The tegmina are of nearly equal width throughout, diagonally truncate at the tip. The characteristic mark is the shape of the supra-anal spine in the male, which has an acute notch at the tip; on each side of the notch, the lobes taper to a rounded point, instead of being truncate, as in another species, not found here.

Measurements:—Length of body, 20 mm.; of tegmina, 34 mm.; of hind femora, 21 mm.; of antennae, 32 mm.; greatest width of tegmina, 9 mm.; of anterior margin of pronotum, 2.5 mm.; of posterior margin, 4 mm.

25. *Scudderia furcata* Brunner.—The specimens found were green, excepting for the red hind tibiae. The supra-anal spine in the male, has a round notch at the tip. The pronotum is of nearly equal width throughout, the tegmina rather narrow.

Measurements:—Length of body, 20 mm.; of tegmina, 30 mm.; of hind femora, 23 mm.; width of tegmina, 6.5 mm.; of front margin of pronotum, 2.5 mm.; of hind margin, 3.5 mm.

Genus Xiphidium Serville.

"This genus includes our smallest winged Locustidae. The vertex projects forward and slightly upward in the form of a rounded tubercle which is hollowed out on the sides for the reception of the basal joint of the antennae. * * * Spines of prosternum very short and weak; often mere cone-shaped protuberances. Wing covers narrow, straight, rounded at the end, often varying much in length for the same species,

but for the most part shorter than the abdomen. Wings usually a little shorter than the wing covers. Stridulating organ of male well developed, the veins prominent, light brown in color, and with the middle transparent. Hind femora of medium length, stout at base; mostly unarmed beneath. Ovipositor narrow, straight, or but slightly curved, oftentimes of excessive length. Anal plates of male not prolonged; the cerci usually much swollen, and toothed at base on the inner margin." —Blatchley.

26. *Xiphidium fasciatum* (De Geer).—The face is quite straight, very oblique, with a scarcely-marked frontal costa; vertex about the width of the basal joint of the antennae, which often extend to the tip of the out-stretched hind leg. Pronotum truncate on front margin, rounded posteriorly. Tegmina shorter than wings, but considerably longer than the abdomen; stridulating organ conspicuous on male, just back of the pronotum.

Color:—General color green. Tegmina and basal part of ovipositor light reddish brown; dark reddish brown stripe extending along dorsal surface, from the vertex to the tip of the abdomen; sometimes a dark stripe on the hind femora.

Measurements:—Length of body, male, 12 mm.; female, 14 mm.; tegmina, male, 13 mm., female, 14 mm.; hind femora, male, 10.5 mm., female, 12 mm.; antennae, 30 mm.; ovipositor, 8 mm.

FAMILY GRYLLIDAE.

"The third family of Orthoptera belonging to the sub-order Saltatoria comprises the Gryllidae or crickets. From the other Orthopterous insects they may be distinguished by having the wing covers flat above and bent abruptly downward at the sides; the tarsi or feet, three-jointed, without pads between the claws; the fore coxae longer than broad. Ocelli or simple eyes are present in the majority of species, while the antennae, like those of the Locustidae, are long, slender, and many jointed. The hearing organ, when present, is, as there, situated on the base of the fore tibiae.

"The tympanum, or calling organ of the male, is also, as in the Locustidae, located near the base of the dorsal surface of the tegmina, but is wider and broader than in the preceding family, extending across both anal and median areas of the tegmina. * * *

"The inner wings of the crickets are, for the most part, short, weak, and comparatively useless as flying organs, though sometimes they are nearly twice as long as the outer pair. * * * These insects, therefore, travel mostly by leaps, and, in the course of time, their hind femora have thus become greatly enlarged.

"The ovipositor of the female is usually a long cylindrical spear-shaped organ, consisting apparently of two pieces. Each of these halves, however, when closely examined, is seen to be made up of two pieces so united as to form a groove on the inner side, so that when the two halves are fitted together, a tube is produced, down which the eggs pass to the repository in the earth or twig, fitted to receive them.

"Most species are represented in the winter by the eggs alone. A few, however, pass the cold season as nymphs or as adults. The mole crickets are said to exist for several years."—Blatchley.

Key to Genera and Species of Gryllidae.

I. Second tarsal joint minute; hind tibiæ slender, armed with spines, between which are minute teeth.

Genus *Oecanthus*.

1. Antennæ either entirely black, or with two black marks on each of the first two joints, those of the basal joint confluent at the top, the inner one the longer.

27, *fasciatus*.

2. No black marks excepting on the first two joints of the antennæ, each of which joints has two parallel marks.

28, *quadripunctatus*.

II. Second tarsal joint minute; tibæ stout, armed with stout immovable spines only; fore tibiæ with hearing organ on both faces.

Genus *Gryllus*.

1. Pronotum not over 5 mm. wide; tegmina, ovipositor, circi, and legs reddish brown. 29, *arenaceous*.
2. Pronotum over 6 mm. wide; all black, excepting inner side of hind femora; ovipositor never over 15 mm. long.

30, *pennsylvanicus*.

Genus Occanthus Serville.

The tree-crickets are weak looking insects, with small hanging heads, which taper to narrow labiae; slender legs; wings and tegmina very pale green or hyaline; spindle-shaped abdomens. In the female the tegmina are more closely wrapped about the body than in the male. They live on tall herbaceous plants such as golden-rod, or on bushes, on the twigs of which their eggs are laid. The species are distinguished by the marks on the first two joints of the antennæ.

27. *Occanthus fasciatus* Fitch.—Vertex and occiput arched, vertex sloping downward to merge into face. Antennæ long, slender, very easily broken in the cyanide bottle. Pronotum narrower, anteriorly, than the head, wider posteriorly, very shallow, so that from the side it gives the appearance of a slender neck. Tegmina broad and flat on top, overlapping the entire width of their dorsal surface; rounded at the apex; wings 1-2 mm. longer than tegmina. Legs very slender.

Color:—General color, light green. Black stripe on mid-dorsal line of head and pronotum. Ventral side of abdomen black; sometimes other black stripes. Antennæ are sometimes entirely black, sometimes have two distinct black marks on each of the first two joints, those on the basal joint being confluent at the top.

Measurements:—Length of body, 12-13 mm.; pronotum, 2 mm.; tegmina, 12 mm.; width of pronotum, front margin, 1.5 mm., hind margin, 2.3 mm.; of dorsal field of tegmina, male, .5 mm.

28. *Oecanthus quadripunctatus* Beutenmüller.—The shape of this species is the same as that of *O. fasciatus*. There are no dark stripes visible from above, though the ventral side of the abdomen is sometimes dark. Color pale green. Antennæ with two separate black marks on each of the first two joints, the inner mark much longer than the outer one. On the basal joint, the inner mark has a small outward pointing hook which does not, however, unite with the outer mark.

Measurements:—Length of body, 11-12 mm.; pronotum, 2.4 mm.; tegmina, 11 mm.

Genus Gryllus Linnaeus.

"All members of the genus Gryllus have the head and globos; the eyes large and rounded; the antennæ thread-like and longer than the body; the pronotum broader than long, and about the width of the head; the hind femora of medium length but much enlarged and well-fitted for leaping; the hind tibiæ with two rows of strong fixed spines, those nearest the apex being the longer; and the hind tarsus with its first joint sulcate above, with a row of minute teeth along each carina. The ovipositor is, in all the species, as long as or longer than the hind femora, and in the same species varies little in length. Most of our species are, however, dimorphic as regards wing length. . . . The inner wings vary much more than the outer, and sometimes are wholly lacking."—Blatchley.

29. *Gryllus arenaceous* Blatchley.—Body slender. Head black, about the width of pronotum, vertex swollen above pronotum; lower part of face reddish brown. Pronotum black; length about .7 of width; margins truncate, median impression on anterior half, a series of small impressions on each side. Tegmina red-brown, lighter at humeral angle, overlapping, wings shorter than tegmina. Legs reddish brown or black. Ovipositor reddish brown.

Measurements:—Length of body, 15 mm.; pronotum, 3.5 mm.; tegmina, 9 mm.; hind femora, 10 mm.; ovipositor, 16.5 mm.; width of pronotum, 5 mm.

30. *Gryllus pennsylvannicus* Burmeister.—Body stout and broad. Head a little wider than pronotum, vertex not swollen above pronotum; length of pronotum 7-12 its width, margins truncate, median impression at both anterior and posterior margins, but not meeting in the middle. Tegmina overlapping, reaching to tip of abdomen; wings often longer than tegmina, projecting behind like a tail.

Color:—Black excepting red-brown on the base of the hind femora, and golden brown tinge on the tegmina, which also have a yellowish stripe along the humeral angle. When first moulted, the insect is covered with a gray pubescence, which later wears off. A freshly moulted adult was found August 10.

Measurements:—Length of body, 17 mm.; pronotum, 3.5 mm.; tegmina, 10.5 mm.; ovipositor, 13.5 mm.

GLOSSARY.

Arolium.—The small pad between the claws at the end of the tarsus.

Calcaria.—Claws or spurs at the end of the tarsus.

Carina.—A narrow ridge or keel.

Cerci.—The longer and more prominent pair of male abdominal appendages.

Clypeus.—A rectangular plate in the lower part of the face, to which the labrum is attached.

Costa.—A broad longitudinal ridge. The ridge along the middle of the face.

Coxa.—The basal joint of the leg, between the body and the femur.

Cristate.—Crested.

Elytra.—Wing covers.

Exserted.—Protruding.

Fastigium.—The extreme front of the top of the head; it joins the occiput with the face.

Femora.—Thighs.

Fossa.—A depression or groove.

Foveola.— Two small depressions on the margin of the vertex, near the compound eyes.

Furcula.—A forked process from the last abdominal segment, which lies over the supra-anal plate.

Fuscous.—Very dark brown, nearly black.

Lobe, lateral.—Of pronotum, the nearly vertical side plates. In Tettixes, a projection in front of the lateral sinus, and between the first and second legs.

Median lobe, in Tettixes, separates the lateral from the posterior sinus.

Mesonotum.—The dorsal part of the middle segment of the thorax.

Metanotum.—The dorsal part of the last segment of the thorax.

Metazona.—The part of the pronotum behind the principal sulcus.

Occiput.—The top of the head, where it joins the thorax.

Ocelli.—Simple eyes, found, one in the middle of the face, and one near each antenna.

Ovipositor.—Four prongs, more or less united, extending from the last abdominal segment of the female, with which the eggs are placed.

Pilose.—Hairy.

Pronotum.—Dorsal part of first thoracic segment.

Prosternum.—Ventral part of first thoracic segment.

Prozona.—That part of the pronotum in front of the principal sulcus.

Pubescent.—Covered with soft, short and not crowded hair, wool, or down.

Punctate.—Finely dotted or pitted.

Quadrate areolate.—Divided into four-sided spaces.

Reticulate.—With net-like veins or markings.

Rugose.—Rough or wrinkled.

Sinus.—Lateral, in Tettixes, a notch in the pronotum just above the second leg. Posterior sinus, a small notch just back of the lateral sinus.

Sub-.—A prefix meaning nearly, somewhat.

Sulcus.—A narrow groove; principal sulcus, the deeper sulcus crossing the pronotum.

Tarsus.—The foot, made up of 3-4 joints.

Tectiform.—Roof like.

Tibia.—The section of the leg between the thigh and foot.

April, 1911.

RESULTS OF THE MERSHON EXPEDITION TO THE CHARITY ISLANDS, LAKE HURON.

PRELIMINARY REPORT ON THE COLEOPTERA.

A. W. ANDREWS.

The writer spent eight days, June 19 to 26, and July 16 to 17, on Charity Island, and one-half day, June 23, on Little Charity Island collecting Coleoptera for the Mershon Expedition.* Headquarters were established at the lighthouse on the larger island.

Charity Island, where most of the work was done, is heavily wooded, and is in an almost virgin condition. The largest and most common trees are: Norway pine, *Pinus resinosa* Ait., red oak, *Quercus rubra* L., scarlet oak, *Quercus coccinea* Moench., yellow oak, *Quercus ellipsoidalis* E. J., white elm, *Ulmus americana* L., red maple, *Acer rubrum* L., sugar maple, *Acer saccharum* Marsh, white birch, *Betula alba L.*, cottonwood, *Populus deltoides* Marsh, and mixed with these, are medium and small trees of white pine, *Pinus strobus* L., common poplar, *Populus tremuloides* Michx. and others. A variety of trees and shrubs as basswood, *Tilia americana*, different species of willow and several species of dogwood grow on the edge of the woods bordering the shores.

Charity Island proved to be very rich in Coleoptera. The collection has not been completely worked up, but it is estimated that about five hundred species and ten thousand specimens were collected in the short space of ten days. In this paper the writer has only attempted a general statement of the conditions. It is to be followed by a complete report when the material has all been worked up.

One of the most striking facts about the distribution of the beetles on Charity Island was their great abundance on the northeast shore. During the June trip, two small gales from the northeast made collecting very good on this shore. The waves brought many insects to the beach, most of them alive and active, some dead and a few in a decayed condition, showing long immersion in the water.

The living beetles, as soon as they reached the sand or rocks, crawled up the beach. Some of these crawled upon boards and logs, many went underneath them and some made cells in the sand. Most of the species, however, remained thus sheltered for a number of hours and then dispersed among the trees and shrubbery lining the shore.

The great number of insects in the washup attracted many species of beetles from the shrubbery, logs, etc., situated at some distance from the water. These beetles preyed on the living insects and fed on the dead ones on the beach.

Various species of beetles were found in numbers running on the sand and rocks. The species *Calosoma frigidum* Kirby, was found in hun-

*For a general account of this expedition see Ruthven, Alexander G., Science, N. S., XXXIII, pp. 208-209.

dreds. Other species, in more limited numbers, were *Calosoma scrutator* Fab., *C. Calidum* Fab., *and Carabus macander* Fisch. (which appeared in July).

Dytiscidæ were found in the washup crawling on the sand and under boards and logs. Many species of Curculionidæ were found on boards, logs and rocks, in some cases fifty or more individuals of the same species occurring above and beneath the same ten-foot board. Several species of Coccinellidae, such as *Hippodamia parenthesis* Say, congregated in such numbers on some of the rocks and logs as to make the latter look reddish at a little distance.

To summarize, then, the conditions on this shore (northeast), great numbers of beetles were found on and under boards and logs, on the rocks and large stones, in the rock pools and by beating the foliage of the trees and shrubs near the shore line. Among them were the following groups: Carabidae, Elateridae, Dysticidae, Scarabaeidae, Coccinellidae, Curculionidae, all in great numbers and varieties of species. Tenebrionidae and Buprestidae in lesser numbers and species on top of boards and logs and Staphylinidae and others in still lesser numbers and species underneath boards and debris.

The writer believes that most of the Coleoptera found on the beach and shores are species that breed on the Island. These beetles, presumably, fly out at night over the water until exhausted and then drop, the waves washing them back on the beach, in most cases not much the worse for their experience. Coleoptera were most common on this shore (northeast), when the wind and waves were coming from the direction of Lake Huron. This would mean that, if the beetles were blown from other shores, they would be in the water a number of days and consequently not active and able to take care of themselves. But, on the contrary, they were mostly very active, which presumably indicates that they had not been in the water any great length of time and had not drifted for any distance. For instance, the writer found three specimens of *Acmaeops proteus* Kirby, on a log within a space of one foot. They were the only ones found on the Island, and it is not at all likely that they could float for days and then land together. The Lachnosterna, being night fliers, were found in great numbers, both dead and alive, on the shore and beach, the living in many cases making cells in the sand under boards and logs. The rare, *Lachnosterna albina* Burm., was found in some numbers, this being the first record for Michigan. Furthermore in the washup few beetles were found that could not live under the conditions as they existed on the Island. Since no trees are felled on the island, very few species of Buprestidae, Cerambycidae, Cleridae, etc., were found. This was because the absent species require freshly cut timber and stumps or drying logs. Some that were found on the beach were mostly badly decayed, showing that they had come from some distance.

On the southwest shore the conditions differ much from those of the northeast shore. Very few species of the above groups were found. This was apparently partly because this shore was not so favorable for active movement, a more or less wide stretch of dry, loose sand between the shingly beach and the edge of the woods and shrubbery preventing the beetles from crawling or running freely; and it was probably partly

owing to the direction of the winds, although this was not worked out.

Chrysomelidae, Cerambycidae, Elateridae and Curculionidae were found in the willows, shrubs and trees growing at a short distance parallel with the southwest shore. They were also found on the pines and oaks, meadow roses, *Rosa blanda* Ait., milkweed, *Asclepias syriaca* L., and on other plants, by searching the flowers or beating the foliage and branches. In a few fungi found in the vicinity of the southwest shore, a number of species of fungus beetles were also discovered.

In the water, mud and matted duck-weed, *Spirodela polyrhiza* L., of the pond near the southwest shore, a number of species of Dytiscidae were found by dredging. Several species of Gyrinidae were swimming in numbers on the surface. On the lily pads, several species of Donacia were to be seen.

On a sandy path near this shore (southwest), the larvae of Cicindelidae had pits. These were probably the larvae of *C. repanda,* as the adult of this species was taken there.

In the interior of the island Coleoptera were scarce. A number of species of Cerambycidae and others were taken on blossoms of flowering shrubs. *Xylorctes satyrus* Fab. found crawling on the ground, and a number of species of bark beetles and Staphylinidae comprised about all the forms noted in this locality. The other shores also did not yield many beetles either in species or in numbers, although seemingly favorable.

Very few potato-beetles, *Doryphora 10-lineata* Say, "usually very common in the washup on lakes" were found. Nearly all were dead, but a number, both adults and larvae, were found feeding on night-shade, *Solanum dulcamara* L.

The writer found Cicindelidae scarce in numbers and species on the island, while on the mainland, at Caseville, they were common.

Passalus cornutus Fab. and several other species common on the mainland were not found at any place.

As no domestic animals were kept on the island excepting pigs, very few species of dung beetles were found, none on the beach and only a few species near the pig-pen. These dung-beetles were common on the mainland.

The lighthouse did not seem to attract beetles at all. A few were attracted to the window screens by the lamplight, others were observed on the walls of whitewashed buildings, and a number of species flew around at night between the buildings. A few species of Elateridae, Scarabaeidae and Tenebrionidae were taken in the lantern trap operated in the woods near the lighthouse by Dr. Newcomb. Some of these and other species were also taken at sugar lures on trees, namely *Calosoma frigidum* and others.

The following method used by the writer proved especially successful in taking Coleoptera on the island. Boards placed end to end on the damp sand, out of reach of the waves, collected immense numbers of beetles. The beetles coming out of the water crawled on top and underneath the boards and logs, while those coming from the shrubbery and timber to prey on the living and dead insects on the shore and beach sought the shelter of these same boards and logs at the approach of daylight.

April, 1911.

THE OCCURRENCE OF A CREMASTER MUSCLE IN A WOMAN.

G. MORRIS CURTIS.

This rather unusual anomaly, the occurrence of a distinct *Cremaster* muscle in a human female, is presented, not with the idea of bringing out any point in the structure or development of the human muscular system, but rather for the purpose of adding another to the long list of anomalies found in adult structure, which can be traced to embryological causes. This particular case represents a condition in which an embryological structure, normally retained and made use of by the male only, is retained by the female because of developmental factors.

The *Cremaster* muscle is a thin band of muscular fibers, present normally in the male only, which suspends the testis within the scrotum, attaching to the body wall above; its literal meaning being to suspend. It is supposed to be derived by the dragging down of muscular fibers from the lower border of the abdominal muscles, as the testis descends to its adult position.

Its function is to draw the testis up toward the external inguinal ring or the inguinal canal, this function being more or less developed in man and well developed in rats and squirrels, which can completely retract the testes through the inguinal canal into the body cavity. It may also serve as an additional support to the testis, in some cases, for example in the cat, being represented by a dense fibrous fascia, which is said to be formed from the degeneration of the muscular elements.

That its fibers are voluntary and are derived from striped muscle is evident histologically and in this it differs from the so called *Cremaster internus of Henle,* which is of non-striped muscle and is situated at the distal end of the testis and separated from it by the infundibuliform fascia.

The muscle is described by McMurrich (in Piersol's Anatomy, p. 519) as follows: "The *Cremaster* muscle consists of a series of somewhat scattered loops of muscle tissue derived from the lower part of the internal oblique and to a slight extent from the transversalis. It is attached laterally to Poupart's ligament and medially to the anterior layer of the sheath of the rectus. The loops descend through the inguinal canal along with the spermatic cord, *the muscle being well developed only in the male,* and spread out in the tunica vaginalis communis of the testis and spermatic cord. The loops are united by connective tissue which forms part of the cremasteric fascia. Nerve supply, by the genital branch of the genito-crural nerve. Action, to draw the testis upward towards the external abdominal ring."

The case to be described was found in the dissecting rooms of the Anatomical Laboratory of the University of Michigan. The cadaver was that of a young woman of medium height, much emaciated by tu-

berculosis so that the muscular system was poorly developed. In the preliminary dissection a small rounded swelling was noted in the right inguinal region, approximately under the middle of Poupart's ligament. This was thought to be a hernia at first, but upon complete dissection a patulous finger-like process was seen extending downward and inward from the external inguinal ring, lying anterior to the closely attached round ligament, and lateral to the genital branch of the genito-crural nerve.

The rounded finger-like process was a projection from the peritoneum and had carried with it not only the overlying fascia layers but also some of the muscular. The occurrence of the finger-like process is well known as a persistent processus vaginalis or canal of Nuck. It was 5 cm. long and 1 cm. in diameter. It was covered not only by the enveloping fasciae but distinct muscular loops were seen radiating down along its sides to enclose the whole in a basket of closely interwoven muscular fibers. Most of these fibers descended along its lateral side from the middle of the ligament of Poupart, a few extending from the anterior layer of the rectus sheath and the pubic spine. The whole arrangement was very similar to that seen in the male specimens on neighboring tables.

Small twigs from the genital branch of the genito-crural nerve entered the muscle medially supplying it. The relation to the ilio-inguinal nerve could not be determined as it had been destroyed in dissection. The muscular fibers were closely associated with the accompanying round ligament, on which a few fibers sometimes pass to be described as the *Cremaster* muscle in the female.

The embryological condition by which this anomaly can be explained has to do with the changes occurring in the descent of the testes and ovaries. As they commence their descent an independent change occurs in the lower pubic region resulting in the formation of a shallow inguinal bursa lined by a processus vaginalis of the peritoneum. In the male this processus vaginalis is carried down by the descent of the testis and is made use of as its tunica vaginalis. In the female the original processus vaginalis usually disappears, in this case however persisting as a canal of Nuck and bearing on itself fibers of the abdominal muscles carried down in its growth.

The whole anomaly, then, represents the failure of an embryological structure to be absorbed and its persistence acquiring the adult condition of the opposite sex.

April 2, 1911.

RESULTS OF THE MERSHON EXPEDITION TO THE CHARITY ISLANDS, LAKE HURON.

PLANTS.

C. K. DODGE.

The Charity Islands are situated in Saginaw Bay, a part of Lake Huron, about nine and one-half miles from Caseville in Huron County. The group consists of three islands known as Charity, Little Charity and Gull Islands. Charity Island, which has for a long time been owned and used for light-house purposes by the United States Government, contains about 650 acres and is much longer in the north and south direction than wide. Little Charity is the next largest island and is privately owned and used as a fishing station. It is about 3 acres in extent and nearly round in shape. Gull Island is a small projecting reef and was not visited in the course of this work.

The writer visited the islands in 1908, 1909, and in 1910 with the Mershon Expedition, and thoroughly examined the flora.

It is very evident that since the glacial times these islands have not been connected with the mainland. The islands themselves have been formed by the accumulation of sand upon the rocky reefs that were exposed at these places when the level of Lake Huron was lowered. It is evident that the islands are still in the course of formation, for at the north end of Charity Island there is a submerged bar extending far out into the lake, and at the south end, the water is very shallow for a considerable distance out from shore. On Charity Island exposed rock is now mostly to be seen at the north end, but it is also exposed in some places on the east and west sides; the sand has been blown up into ridges on the shore and the island is for the most part made up of low and nearly parallel sand ridges running in a northerly and southerly direction. In their formation these ridges probably occasionally enclosed lagoons, as they did on the mainland. There is a lagoon ("the pond") at present on the southern end and west side of Charity Island. Between the ridges many low places have become partially filled and partly owing to the collected humus form rich damp soil. It will thus be seen that the three major types of habitats, hydrophytic, mesophytic, and xerophytic are found here.

At the present time the islands are densely covered with trees, shrubs and herbaceous plants. On Charity Island only a small area has ever been cultivated and no stock, except a few swine, has been allowed to roam. The vegetation is thus in a virgin condition. As would be expected, the plant covering is composed of mainland species. But the flora as a whole shows the influence of its isolation. The seeds of nearly all of the forms now found on the islands must in one way or another have been carried across the water from the mainland. As one would expect those plants that have seeds adapted for transportation by wind

or birds are by far the most numerous in species. For example, the willows, poplars, Epilobiums, and many species of the Compositae are well represented. All of these species are scattered far and wide by their wind borne seeds or fruits. Plants producing berries and pulpy fruits, like the dogwoods, hackberry, strawberry, huckleberry, cranberry, juneberry and wild cherries, were probably introduced through the agency of birds. Many of those whose seeds or fruits are not so easily transported are poorly represented on the islands or entirely absent; for example only one beech and one jack pine, both common on the mainland, were found. The hickories and the hazelnut are absent.

The occurrence of two species is not easily explained. The tree known as the hackberry or sugarberry is common on Little Charity, one tree being fourteen inches in diameter and fifty feet in height. The fruit of this species is sweet and pulpy and eaten by birds, but, while it has reached Little Charity Island, not a single specimen was found on Charity Island although the latter is many times larger than Little Charity and situated about the same distance from the mainland. The tree has not been found by the writer on the adjacent mainland, but it is reported by W. H. Wallace as occasionally found near Bayport, Huron County. *Apios tuberosa* Moench, often called the wild bean or ground nut, is another puzzling case. This plant is a beautiful vine that twines and climbs over bushes. It bears numerous chocolate-colored or brown purple flowers in dense short racemes, but in the course of thirty years of observation in eastern Michigan it has never been seen to bear fruit, spreading instead by means of tuberous enlargements of the rootstocks. It bears fruit abundantly in the south and has been reported to do so in Michigan, but it is believed that it only rarely fruits in this state and certainly not often within one hundred miles of Port Huron. It is common on the mainland and frequent on Charity Island, and it is not clear how it could traverse the intervening seven miles of water.

As a rule, sand binding plants are not very prominent, but on Little Charity Island the beach pea almost completely covers the sandy ground on the south side. On Charity Island the low juniper is fairly well established in the sand on the west side of the north end, and the sea sand-reed is abundant and holding down the sand on the shore near the lighthouse. The other characteristic shore plants are not abundant but are the same as on the mainland. The species noted are Pitcher's thistle, *Artemisia caudata, Calamovilfa longifolia, Agropyron dasystachyum,* and *Juncus balticus littoralis.*

The usual weeds found on or near cultivated ground are few and on Charity Island confined mostly to the vicinity of the lighthouse and on Little Charity to the neighborhood of the fishing buildings.

The distribution of trees and shrubs on Charity Island is much the same as on the mainland. Red Oak is dominant on the sand ridges, especially near the beach, and extends to the rich damp ground. Between the ridges and in rich ground on the east side of the north end, white elm, white ash, ironwood, red maple and basswood are frequent. The white pine trees that occur here are not generally very large or prominent but fine trees of red pine are found.

The following list of plants found on the island contains 372 species (exclusive of the three unidentified thorns mentioned later). These species are all found on the mainland to the south but nearly 900 spe-

cies have been noted in the latter place. It will thus be seen that only about one-third of the mainland species have been able to reach or maintain themselves on the island.

LIST OF SPECIES.*

Pteris aquilina L. Common brake.—Common under trees and in open dry ground. Charity Island.

Asplenium filix-foemina (L). Bernh. Lady fern.—Occasional in damp shaded or open ground. Charity Island.

Aspidium thelypteris (L.) Sw. Marsh shield-fern.—Very common in damp shaded or open ground. Charity Island.

Aspidium spinulosum (O. F. Miller) Sw. Spinulose shield-fern.—Frequent in rich shaded ground. Charity Island.

Aspidium spinulosum intermedium (Muhl.) D. C. Eaton. Spinulose shield-fern.—Occasional in damp rich shaded ground. Charity Island.

Onoclea sensibilis L. Sensitive fern.—Very common in damp shaded or open ground. Charity Island.

Osmunda regalis L. Flowering fern.—Occasional in shaded or open wet ground. Abundant in places. Charity Island.

Osmunda cinnamomea L. Cinnamon fern.—Occasional in wet woods. Charity Island.

Botrychium ternatum intermedium D. C. Eaton. Ternate grape-fern. —Occasional on dry ground. One specimen noticed near the lighthouse. Charity Island.

Botrycium virginianum (L.) Sw. Rattlesnake fern.—Frequent in rich woods. Charity Island.

Equisetum arvense L. Common horsetail.—Occasional in dry or damp ground. Charity Island.

Equisetum sylvanticum L. Wood horsetail.—Frequent in damp shaded ground. Charity Island.

Equisetum fluviatile L. Swamp horsetail. Pipes.—Occasional about the pond. Charity Island.

Equisetum hyemale L. Scouring rush.—Occasional in light sandy ground. Charity Island.

Equisetum hyemale intermedium A. A. Eaton. Scouring rush.—Frequent in dry shaded or open ground.

Equisetum hyemale robustum (A. Br.). A. A. Eaton. Scouring rush. —Frequent in dry shaded ground. Charity Island.

Equisetum variegatum Schleich. Variegated equisetum.—Frequent in sand along the beach. Charity Island.

Lycopodium complanatum L. Trailing christmas-green.—Occasional on dry shaded ground. Charity Island.

Salaginella apus (L.) Spring. Creeping selaginella.—Frequent in damp grassy places. Charity Island.

Pinus strobus L. White pine.—Common but mostly small trees. Charity Island.

Pinus banksiana Lamb. Jack pine. Gray pine.—One tree found on the west side, Charity Island, first noticed by N. A. Wood.

*Scientific names after Gray's New Manual of Botany. Many common names have been taken from Britton and Brown's illustrated work.

Pinus resinosa Ait. Red pine. Norway pine.—Common and many large and fine specimens. Charity Island.

Larix laricina (Du Roi) Koch. Tamarack. American Larch.—A few trees near the pond. Charity Island.

Tsuga canadensis (L.) Carr. Hemlock.— Noticed as occasional, but trees not large. Charity Island.

Thuja occidentalis L. White cedar. Arbor vitae.—Common, especially on and near the upper beach. Charity Island.

Juniperus communis L. Common juniper. Occasional in dry woods. Charity Island.

Juniperus communis depressa Pursh. Low juniper.—Mostly on the west side along the upper beach acting as a sand binder. Charity Island.

Typha latifolia L. Common cat-tail. —Occasional in very wet places, noticed in particular near the pond. Charity Island.

Sagittaria latifolia Willd. Broad-leaved arrow-head.—About the pond and occasional in wet sand along the shore. Charity Island.

Alisma plantago-aquatica L. Water plantain.—Occasional in low wet places along or near the beach. Charity Island.

Elodea canadensis Michx. Water-weed.—Abundant in the pond. Charity Island.

Andropogon scoparius Michx. Broom beard-grass.—Frequent in dry ground and on sand ridges. Charity Island.

Andropogon furcatus Muhl. Forked beard-grass.—Frequent on poor sandy ground. Charity Island.

Sorghastrum nutans (L.) Nash. Indian grass. Wood grass.—Frequent in open dry ground and on sand ridges. Charity Island.

Digitaria sanguinalis (L.) Scop. Large crab grass.—As a weed about the lighthouse. Charity Island.

Panicum capillare L. Old witch grass.—As a weed about the lighthouse. Charity Island.

Panicum virgatum L. Switch grass.—Common in sandy open ground and on sand ridges near the upper beach. Charity Island.

Panicum depauperatum Muhl. Starved panicum.—Frequent in open sandy ground. Charity Island.

Panicum dichotomum L. Forked panicum.—Common in sandy shaded ground. Charity Island.

Panicum scribnerianum Nash. Scribner's panicum.—Frequent in dry sandy ground. Charity Island.

Echinochloa crusgalli (L.) Beauv. Barnyard grass.—As a weed about the lighthouse and occasional along the beach. Charity Island.

Setaria glauca (L.) Beauv. Yellow foxtail. Pigeon grass.—As a weed about the lighthouse. Charity Island.

Setaria viridis (L.) Beauv. Green foxtail. Bottle grass.—As a weed about the lighthouse. Charity and Little Charity Islands.

Phalaris arundinacea (L.) Reed canary grass.—Occasional in wet marshy places. Charity Island.

Millium effusum L. Millet grass.—Occasional in rich shaded ground. Charity Island.

Stipa spartea Trin. Porcupine grass.—Occasional on poor sandy ground. Charity Island.

Phleum pratense L. Timothy.—Mostly about the lighthouse. Charity and Little Charity Islands.

Sporobolus cryptandrus (Torr.) Gray. Sand dropseed.—Frequent on sand ridges and on the beach as a sand binder. Charity Island.

Agrostis alba L. Red top.—Frequent in damp ground. Charity Island.

Calamovilfa longifolia (Hook.) Hack. Long-leaved reed-grass.—Common on sand ridges and in sand on and near the upper beach, acting as a sand binder. Charity Island.

Calamagrostis canadensis (Michx.) Beauv. Blue-joint grass.—Occasional in damp open places. Charity Island.

Ammophila arenaria (L.) Link. Sea sand-reed.—In drifting sand along the beach, acting as one of the best sand binders; abundant near the lighthouse. Charity Island.

Cinna arundinacea L. Wood reed grass.—Occasional in damp shaded ground. Charity Island.

Koeleria cristata (L.) Pers. Koeleria.—Occasional on sand ridges. Charity Island.

Deschampsia flexuosa (L.) Trin. Common hair-grass.—Frequent in shaded sandy ground. Charity Island.

Danthonia spicata (L.) Beauv. Common wild oat grass.—Common on dry sandy open ground. Charity Island.

Spartina michauxiana Hitchc. Slough grass. Tall marsh-grass.—In damp ground at the south end of Charity Island.

Phragmites communis Trin. Reed.—About the pond and occasional in wet spots along the beach. Charity Island. In the latter place a root or underground stem more than 20 feet long was noticed running on the surface of the sand toward the water.

Poa compressa L. Canada blue grass. Wire grass. English blue grass.— Frequent on dry sandy ground. Charity Island.

Poa pratensis L. June grass. Kentucky blue grass.—Frequent, but nowhere abundant. Charity and Little Charity Islands.

Festuca octoflora Whit. Slender fescue-grass.—Frequent in open sandy ground. Charity Island.

Festuca ovina L. Sheep's fescue.—Frequent on sand ridges. Charity Island.

Agropyron dasystachyum (Hook.) Scribn. Northern wheat-grass.—Occasional in sand along or near the upper beach especially near the lighthouse, Charity Island. A good sand binder.

Agropyron caninum (L.) Beauv. Awned wheat-grass.—Occasional in open woods. Charity Island.

Elymus canadensis L. Nodding wild rye.—Frequent on and near the upper beach as a sand binder. Charity and Little Charity Islands.

Hystrix patula Moench. Bottle brush-grass.—Common in damp woods. Charity Island.

Cyperus filiculmis Vahl. Slender cyperus.—Occasional on poor dry ground. Charity Island.

Dulichium arundinaceum (L.) Britton. Dulichium.—Occasional in very wet places. Noticed in particular about the pond. Charity Island.

Eleocharis palustris (L.) R. & S. Creeping spike-brush.—Frequent in wet places, especially along the beach. Charity Island.

Eleocharis tenuis (Willd.) Schultes. Slender spike-rush.—Occasional in damp ground. Charity Island.

Scirpus americanus Pers. Three-square.—Common in wet spots along the beach. Charity Island.

Scirpus occidentalis (Wats.) Chase. Western bulrush.—In and about the pond. Occasional in wet sand along the beach. Charity Island.

Scirpus atrovirens Muhl. Dark green bulrush.—Occasional in wet places. Charity Island.

Cladium mariscoides (Muhl.) Torr. Twig-rush.—In very wet places along the beach. Charity Island.

Carex muhlenbergii Schkuhr. Muhlenberg's sedge.—Frequent on dry sandy ground and sand ridges. Charity Island.

Carex stipata Muhl. Awl-fruited sedge.—Occasional in very wet spots. Charity and Little Charity Islands.

Carex pennsylvanica Lam. Pennsylvania sedge.—Common in dry shaded and open ground. Charity Island.

Carex crawei Dewey. Crawe's sedge.—Occasional in damp sand along the beach. Charity and Little Charity Islands.

Carex filiformis L. Slender sedge.—Frequent in very wet places. Noticed in particular about the pond. Charity Island.

Carex hystericina Muhl. Porcupine sedge.—Occasional in wet spots along the beach. Charity and Little Charity Islands.

Carex intumescens Rudge. Bladder sedge. Occasional in rich damp woods. Charity Island.

Arisaema triphylium (L.) Schott. Indian turnip. Jack-in-the-pulpit. —Common in rich woods. Charity Island.

Acorus calamus L. Sweet flag.—On west side of Little Charity, not noticed on Charity Island.

Spirodela polyrhiza (L.) Schleid. Greater duckweed.—Border of pond on water and mud. Charity Island.

Pontederia cordata L. Pickerel-weed.—Noticed in the pond. Charity Island.

Juncus tenuis Willd. Slender rush. Yard rush.—About the lighthouse and along paths. Charity Island.

Juncus balticus littoralis Engelm. Baltic rush.—Frequent in sand along the beach acting as a sand binder. Charity Island.

Juncus alpinus insignis Fries. Richardson's rush.—Frequent along the beach in damp sand. Charity Island.

Juncus alpinus fuscescens Fernald. Richardson's rush.—Occasional along the beach in damp sand. Charity Island.

Luzula saltuensis Fernald. Hairy wood rush. Frequent in damp shaded ground. Charity Island.

Lilium philadelphicum andinum (Nutt.) Ker. Western red lily.—In dry sandy ground. Apparently rare. Charity Island.

Lilium superbum L. Turk's-cap lily.—On the east side in damp ground. Apparently rare. Charity Island.

Asparagus officinalis L. Garden asparagus.—Occasional in dry sandy ground. Charity Island.

Smilacina racemosa (L.) Desf. False spikenard.—Common in damp or dry ground. Charity and Little Charity Islands.

Smilacina stellata (L.) Desf. Star-flowered Solomon's seal.—Common in rich or poor ground. Often noticed along the upper beach. Charity and Little Charity Islands.

Smilacina trifolia (L.) Desf. Three-leaved Solomon's seal.—In mud about pond. Charity Island.

Maianthemum canadense Desf. False lily-of-the-valley.—Common in shaded ground. Charity Island.

Polygonatum biflorum (Walt.) Ell. Small Solomon's seal.—Common in damp shaded ground. Charity Island.

Polygonatum commutatum (R. & S.) Dietr. Great Solomon's seal.—Occasional in shaded ground. Charity Island.

Medeola virginiana L. Indian cucumber-root.—Occasional in rich damp woods. Charity Island.

Trillium erectum L. Ill-scented wake-robin.—Frequent in rich shaded ground. Charity and Little Charity Islands.

Trillium grandiflorum (Michx.) Salisb. Large-flowered wake-robin.—Common in damp shaded ground. Charity Island.

Smilax herbacea L. Carrion-flower.—Frequent in damp shaded ground. Charity Island.

Smilax hispida Muhl. Hispid greenbrier.—Common in damp thickets. Charity and Little Charity Islands.

Dioscorea villosa L. Wild yamroot.—Occasional in damp thickets. Charity and Little Charity Islands.

Iris versicolor L. Larger blue flag.—Occasional in open wet places. Charity and Little Charity Islands.

Sisyrinchium albidum Raf. White blue-eyed grass.—Occasional in damp places. Charity Island.

Cypripedium acaule Ait. Stemless lady's slipper. Moccasin flower.—Frequent in shaded sandy ground. Charity Island.

Habenaria bracteata (Willd.) R. Br. Long-bracted orchis.—A few specimens noticed in shaded ground near the pond. Charity Island.

Spiranthes cernua (L.) Richard. Nodding ladies' tresses.—In wet places along the west beach. Charity Island.

Corallorhiza maculata Raf. Large coral-root.—Occasional in rich shaded ground. Charity Island.

Liparis loeselii (L.) Richard. Fen orchis.—In damp places along the west beach. Charity Island.

Salix nigra Marsh. Black willow.—Mostly small shrubs on or near the beach. Charity and Little Charity Islands.

Salix amygdaloides Anders. Peach-leaved willow. —Frequent in damp open ground and in woods with other trees. Charity and Little Charity Islands.

Salix lucida Muhl. Shining willow.—In wet places along the beach and open thickets. Charity and little Charity Islands.

Salix longifolia Muhl. Sand bar willow.—Noticed mostly in wet places along the beach. Charity and Little Charity Islands.

Salix glaucophylla Bebb. Broad-leaved willow.—Occasional along the beach acting as a sand binder. Charity and Little Charity Islands.

Salix discolor Muhl. Glaucous willow.—Frequent in low wet ground. Charity and Little Charity Islands.

Salix humilis Marsh. Prairie willow.—Occasional on poor sandy ground. Charity Island.

Salix rostrata Richards. Bebb's willow. Little Charity Island.

Populus tremuloides Michx. Common poplar.—American aspen.—Frequent. Charity and Little Charity Islands.

Populus grandidentata Michx. Large-toothed aspen. Occasional. Charity Island.

Populus balsamifera L. Balsam poplar.—Common on and near the beach. Trees usually small and often acting as a sand binder. Charity and Little Charity Islands.

Populus deltoides Marsh. Cottonwood—Common. Many large trees in woods and small trees or shrubs on and near the beach. Charity and Little Charity Islands.

Myrica gale L. Sweet gale.—In low wet ground. Apparently rare. Charity Island.

Ostrya virginiana (Mill.) K. Koch. Ironwood.—Frequent in rich ground with other trees at the north end. Charity Island.

Betula alba L. White birch. Paper birch. Canoe birch.—Common with other trees. Charity Island.

Alnus incana (L.) Moench. Speckled alder. Hoary alder.—Common in low ground. Charity Island.

Fagus grandifolia Ehrh. American beech.—One large tree found on the east side and first noticed by Charles McDonald. Charity Island.

Quercus alba L. White oak.—A few small trees on Little Charity, but not noticed on Charity Island.

Quercus macrocarpa Michx. Bur oak.—A few trees found on Little Charity, but not noticed on Charity Island.

Quircus bicolor Willd. Swamp white oak.—A few trees noticed in rich ground at the north end of Charity Island.

Quercus rubra L. Red oak.—Common on poor sandy ground, one of the dominant trees. Charity Island.

Quercus coccinea Moench. Scarlet oak.—A number of trees on the east side of Charity Island are referred to this species.

Quercus ellipsoidalis E. J. Hill. Yellow oak.—Frequent on sandy ground near the upper beach, especially on east side. Charity Island.

Ulmus americana L. White elm. American elm.—Common with other trees in rich ground. Charity and Little Charity Island.

Celtis occidentalis L. Hackberry. Sugarberry.—Common on Little Charity, but not noticed on Charity Island.

Urtica gracilis Ait. Slender nettle.—Occasional in damp open places and damp woods. Charity and Little Charity Islands.

Laportea canadensis (L.) Gaud. Wood nettle.—Common in rich woods. Charity Island.

Pilea pumila (L.) Gray. Richweed. Clearweed.—Frequent in rich shaded ground. Charity Island.

Comandra umbellata (L.) Nutt. Bastard toad-flax.—Common in dry ground. Charity Island.

Rumex crispus L. Yellow dock.—About the lighthouse and occasional along the beach. Charity and Little Charity Islands.

Polygonum aviculare L. Knotgrass.—Noticed about the lighthouse and as occasional on dry ground in other places. Charity Island.

Polygonum amphibium L. Water persicaria.—In and about the pond. Charity Island.

Polygonum muhlenbergii (Meisn.) Wats. Swamp persicaria.—In and about the pond. Charity Island.

Polygonum persicaria L. Lady's thumb.—About the lighthouse as a weed and occasional in damp sand along the beach. Charity Island.

Polygonum convolvulus L. Black bindweed. About the lighthouse as a weed and occasional along the beach. Charity and Little Charity Islands.

Polygonum cilinode Michx. Fringed black bindweed.—Noticed only on Little Charity Island where it is abundant in sandy ground.

Polygonum scandens L. Climbing false buckwheat.—Occasional in damp thickets. Charity Island.

Polygonella articulata (L.) Meisn. Coast jointweed.—Common on sand ridges, especially on the west side. Charity Island.

Chenopodium hybridum (L.) Maple-leaved goosefoot.—As a weed about the lighthouse and occasional along the beach, Charity and Little Charity Islands.

Chenopodium album L. Pigweed. Lamb's quarters.—As a weed about the lighthouse and elsewhere. Charity and Little Charity Islands.

Atriplex patula hastata (L.) Gray. Halberd-leaved orache.—As a weed about the lighthouse. Charity Island.

Salsola kali tenuifolia C. F. W. Mey. Russian thistle.—A few specimens noticed about the lighthouse. Charity Island.

Amaranthus retroflexus L. Amaranth pigweed. Green amaranth.—As a weed about the lighthouse and elsewhere. Charity and Little Charity Islands.

Amaranthus graecizans L. Tumble weed.—As a weed about the lighthouse and occasional along the beach. Charity Island.

Amaranthus blitoides Wats. Prostrate amaranth.—As a weed about the lighthouse. Charity Island.

Silene antirrhina L. Sleepy catchfly.—Occasional on sand ridges. Charity Island.

Saponaria officinalis L. Bouncing bet. Soapwort.—In sand near the lighthouse. Charity Island.

Nymphaea advena Ait. Yellow water lily. Cow lily.—A few specimens in the pond. Charity Island.

Castalia tuberosa (Paine) Greene. Tuberous white water lily. White water lily.—Noticed in the pond. Charity Island.

Ranunculus abortivus L. Small-flowered crowfoot.—Common in damp rich woods. Charity Island.

Ranunculus recurvatus Pers. Hooked crowfoot.—Occasional in rich shaded ground. Charity Island.

Ranunculus pennsylvanicus L. f. Bristly crowfoot.—Occasional in damp grassy open places. Charity Island.

Thalictrum dioicum L. Early meadow rue.—Common in rich shaded ground. Charity Island.

Thalictrum dasycarpum Fisch. & Lall. Purple meadow rue.—Occasional in damp open ground. Charity Island.

Hepatica triloba Chaix. Round-lobed liver-leaf.—Frequent in rich shaded ground. Charity Island.

Hepatica acutiloba DC. Sharp-lobed liver-leaf.—Common at the north end in damp rich shaded ground. Charity Island.

Anemone cylindrica Gray. Long-fruited anemone.—Frequent in sandy ground and on sand ridges. Charity Island.

Anemone virginiana L. Tall anemone.—Occasional in rich shaded ground. Charity Island.

Aquilegia canadensis L. Wild columbine. Occasional in sandy shaded ground. Charity and Little Charity Island.

Menispermum canadense L. Moonseed.—Occasional on border of thickets and in damp open woods. Charity Island.

Podophyllum peltatum. Mandrake. May apple.—Small patches noticed in shaded ground. Charity Island.

Sanguinaria canadensis L. Bloodroot.—Common at the north end in rich shaded ground. Charity Island.

Lepidium virginicum L. Wild peppergrass.—As a weed about the lighthouse. Charity Island.

Lepidium apetalum Willd. Apetalous peppergrass.—As a weed about the lighthouse and occasional on the beach. Charity Island.

Capsella bursa-pastoris (L.) Medic. Shepherd's purse.—As a weed about the lighthouse. Charity Island and Little Charity Island.

Cakile edentula (Bigel.) Hook. American sea rocket.—Common in sand along the beach. Charity Island.

Sisymbrium officinale (L.) Scop. Hedge mustard.—As a weed near the lighthouse. Charity Island.

Erysimum cheiranthoides L. Worm-seed mustard.—As a weed about the lighthouse and occasional on the beach. Charity Island.

Dentaria laciniata Muhl. Cut-leaved toothwort.—Abundant in rich woods on the east side. Charity Islands.

Arabis lyrata L. Lyre-leaved rock-cress.—Common on dry sandy ground. Charity Island.

Arabis drummondi Gray. Purple rock-cress.—In rich woods on the east side. Charity Island.

Arabis laevigata (Muhl.) Poir. Smooth rock-cress.—On sandy ground, mostly at the north end fringing the upper beach. Charity and Little Charity Islands.

Ribes cynosbati L. Prickly gooseberry.—Frequent in rich shaded ground. Charity and Little Charity Islands.

Ribes floridum L'Her. Wild black currant.—Common in damp rich shaded ground. Charity Island.

Hamamelis virginiana L. Witch-hazel.—Common on dry ground. Charity Island.

Platanus occidentalis L. Sycamore. Button-wood.—Many large specimens in rich ground with other trees on the east side; numerous small trees and shrubs noticed along the beach. Charity Island.

Spiraea salicifolia L. Willow-leaved meadow-sweet.—Frequent in damp ground about low places; noticed in particular near the pond. Charity Island.

Pyrus malus L. Common apple.—Frequent throughout. Charity Island.

Pyrus melanocarpa (Michx.) Willd. Black chokeberry.—Frequent in damp spots; abundant about the pond. Charity Island.

Amelanchier canadensis (L.) Medic. June-berry. May-cherry.—Frequent throughout. Charity Island.

Amelanchier oblongifolia (T. & G.) Roem. Shadbush.—In sandy ground and on sand ridges. Charity Island.

Amelanchier spicata (Lam.) C. Koch. Rou*n*d-leaved June-berry.—Frequent throughout. Charity and Little Charity Islands.

Crataegus crus-galli L. Cockspur thorn.—Occasional in open ground on the west side. Charity Island.

Crataegus punctata Jacq. Large-fruited thorn.—Frequent throughout. Charity Island. Three other species of Crataegus not identified, or yet named, were noticed—one fine tree standing near the lighthouse.

Fragaria virginiana Duchesne. Common strawberry. Virginia strawberry.—Common in both rich and poor ground. Charity and Little Charity Islands.

Potentilla monspeliensis L. Rough cinquefoil.—Occasional as a weed about the lighthouse and along the beach. Charity Island.

Potentilla argentea L. Silvery cinquefoil.—Occasional on sandy ground and on sand ridges. Charity Island.

Potentilla palustris (L.) Scop. Marsh five-fingers.—Noticed about the pond. Charity Island.

Potentilla anserina L. Silverweed.—Occasional on and near the beach. Charity and Little Charity Islands.

Potentilla canadensis L. Five-finger.—Occasional on sandy ground, sand ridges, and along the beach. Charity Island.

Geum canadense Jacq. White avens.—Common in rich woods. Charity Island.

Rubus idaeus aculeatissimus (C. A. Mey.) Regel & Tiling. Wild red raspberry.—Frequent on dry sandy ground. Charity and Little Charity Islands.

Rubus triflorus Richards. Dwarf raspberry.—Common in damp rich woods and thickets. Charity Island.

Rubus occidentalis L. Black raspberry. Black Caps. Frequent in rich woods and thickets. Big Charity Island.

Rubus alleghenicnsis Porter. High bush blackberry.—Frequent in dry open woods. Charity and Little Charity Islands.

Rubus hispidus L. Running swamp blackberry.—Frequent in woods at the south end. Charity Island.

Rubus villosus Ait. Dewberry.—Common on sandy ground and sand ridges. Charity Island.

Agrimonia griposepala Wallr. Tall hairy agrimony.—Occasional in open woods. Charity Island.

Rosa blanda Ait. Meadow rose.—Common on dry open ground. Charity Island.

Rosa carolina L. Swamp rose.—Frequent in wet places, especially about the pond. Charity Island.

Prunus serotina Ehrh. Wild black cherry. —Frequent with other trees. Charity Island.

Prunus virginiana L. Choke cherry.—Common with other trees. Charity and Little Charity Islands.

Prunus pennsylvanica L. F. Wild red cherry.—Frequent on poor open ground, especially on the west side. Charity Island.

Prunus pumila L. Sand cherry.—Abundant in spots on and near the beach, usually acting as a sand binder. Charity and Little Charity Islands.

Prunus cerasus L. Common cherry. Sour cherry.—Spreading near an old garden at the north end. Charity Island.

Prunus americana Marsh. Wild plum.—Occasional on the west side. Charity Island.

Trifolium repens L. White clover.—About the lighthouse and occasional in other places. Charity and Little Charity Islands.

Desmodium canadense (L.) DC. Showy tick-trefoil.—Occasional on and near the beach. Charity Island.

Lespedeza capitata Michx. Round-headed bush clover.—Occasional on sand ridges. Charity Island.

Lathyrus maritimus (L.) Bigel. Beach pea.—Frequent on Charity Island in sand on the beach, a good sand binder. Abundant on Little Charity Island.

Lathyrus palustris L. Marsh vetchling.—Frequent in low grassy places. Charity and Little Charity Islands.

Lathyrus palustris myrtifolius (Muhl.) Gray. Myrtle-leaved marsh pea.—Occasional in damp places. Charity Island.

Apios tuberosa Moench. Wild bean. Groundnut.—Frequent throughout. Charity Island.

Amphicarpa monoica (L.) Ell. Hog peanut.—Frequent in thickets. Charity Island.

Geranium maculatum L. Wild cranesbill.—Common in rich woods. Charity Island.

Geranium robertianum L. Herb Robert.—Abundant in rich woods on the east side. Charity Island.

Euphorbia preslii Guss. Upright spotted spurge.—Occasional in dry ground. Charity Island.

Euphorbia cyparissias L. Cypress spurge.—In sand about the lighthouse. Charity Island.

Rhus typhina L. Staghorn sumach.—Frequent in dry or damp ground. Charity and Little Charity Islands.

Rhus toxicodendron L. Poison ivy. Poison oak.—Very abundant over the islands. Stems upright, often 2 or 3 feet and more high with leaves and fruit at the top. Although the islands are mostly covered with a dense forest, not even one case of climbing trees was noticed. Perhaps it will be interesting to note that at Point Pelee on the north shore of Lake Erie, Essex Co., Ontario, about 150 miles farther south poison ivy often takes complete possession of trees 50 feet and more high and the vine is often more than three inches in diameter. Some authors recognize the tree climbing form as *Rhus toxicodendron radicans* (L.) Farr. Climbing poison ivy. Charity and little Charity Islands.

Ilex verticillata (L.) Gray. Winterberry. Black alder.—Common especially about the pond. Charity Island.

Celastrus scandens L. Climbing bittersweet.—Known in Michigan and western Ontario as bittersweet. Common in woods and thickets. Charity Island.

Acer spicatum Lam. Mountain maple.—Occasional in woods. Charity Island.

Acer saccharum Marsh. Sugar maple.—Frequent especially on the east side. Charity Island.

Acer saccharinum L. Silver maple.—Occasional in woods with other trees. Charity and Little Charity Islands.

Acer rubrum L. Red maple.—Common in rich ground with other trees. Charity Island.

Impatiens biflora Walt. Spotted touch-me-not.—Common in damp places. Charity Island.

Ceanothus americanus L. New Jersey tea.—Red-root.—Common in dry ground. Charity Island.

Ceanothus ovatus Desf. Smaller red-root.—Noticed on the east side in dry ground, apparently rare. Charity Island.

Psedera vitacea (Kneer) Greene. American ivy. American woodbine. —Common in woods. Charity and Little Charity Islands.

Vitis vulpina L. River-bank grape.—Common throughout. Charity and Little Charity Islands.

Tilia americana L. Basswood.—Common with other trees. Charity and Little Charity Islands.

Hypericum kalmianum L. Kalm's St. John's-wort.—Frequent in damp places along the beach. Charity Island.

Hypericum virginicum L. Marsh St. John's-wort.—In wet marshy places, especially about the pond. Charity Island.

Helianthemum canadense (L.?) Michx. Long-branched frostweed.—Common on dry sandy ground. Charity Island.

Viola sororia Willd. Wooly blue violet. Occasional in moist, shaded ground. Big Charity Island.

Viola pubescens Ait. Downy Yellow Violet. In dry rich ground. Big Charity Island.

Viola scabriuscula Schwein. Smooth yellow violet.—Common in rich woods. Charity Island.

Epilobium angustifolium L. Great willow-herb. In recent years also acquiring the name of fireweed.—Frequent. Charity Island.

Epilobium adenocaulon Haussk. Northern willow-herb.—Occasional in damp ground. Charity Island.

Oenothera biennis L. Common evening primrose.—Common in dry sandy ground and along the beach. Charity Island.

Circaea lutetiana L. Enchanter's nightshade.—Common in rich woods. Charity Island.

Aralia racemosa L. Spikenard.—Frequent in rich woods. Charity Island.

Aralia nudicaulis L. Wild sarsaparilla.—Abundant in rich woods and often in shaded sandy ground. Charity Island.

Sanicula marilandica L. Sanicle. Black snakeroot.—Abundant in rich woods. Charity Island.

Osmorrhiza longistylis (Torr.) DC. Smoother sweet cicely.—Frequent in rich woods and thickets. Charity and Little Charity Islands.

Cicuta maculata L. Water hemlock. Beaver poison.—Noticed in damp open ground near an old garden at the north end. Root very poisonous. Charity Island.

Cicuta bulbifera L. Bulb-bearing water hemlock.—Occasional in wet open places. Root supposed to be very poisonous. Charity Island.

Cornus canadensis L. Dwarf cornel. Bunchberry.—In damp woods at the north end. Charity Island.

Cornus circinata L'Her. Round-leaved cornel.—Common. Charity Island.

Cornus amomum Mill. Silky cornel. Kinnikinnik.—Frequent in low open places. Charity Island.

Cornus stolonifera Michx. Red-osier dogwood.—Occasional in damp or dry sandy ground. Charity and Little Charity Islands.

Cornus paniculata L'Her. Panicled dogwood.—Frequent. Charity Island.

Cornus alternifolia L. f. Alternate-leaved Cornel.—Frequent in woods. Charity and Little Charity Islands.

Chimaphila umbellata (L.) Nutt. Prince's pine. Pipsissewa.—Frequent in shaded dry ground, especially under pines. Charity Island.

Pyrola secunda L. One-sided wintergreen.—Occasional in dry shaded ground. Charity Island.

Pyrola elliptica Nutt. Shin-leaf.—Occasional on poor shaded ground. Charity Island.

Pyrola americana Sweet. Round-leaved wintergreen.—Occasional in dry shaded ground. Charity Island.

Monotropa uniflora L. Indian pipe.—Occasional. Noticed by N. A. Wood. Charity Island.

Epigaea repens L. Mayflower. Trailing arbutus.—A few specimens on Charity Island in dry ground under trees near the lighthouse. Noticed by Charles McDonald.

Gaultheria procumbens L. Teaberry. Known in Michigan and western Ontario as wintergreen.—Common in sandy open or shaded ground. Charity Island.

Arctostaphylos uva-ursi (L.) Spreng. Bearberry.—Common in sandy ground on and near the upper beach, often acting as a sand binder. Charity Island.

Gaylussacia baccata (Wang.) C. Koch. Black huckleberry.—Common in shaded or open sandy ground. Charity Island.

Vaccinium pennsylvanicum Lam. Low sweet blueberry.—Frequent in sandy open or shaded ground. Charity Island.

Vaccinium macrocarpon Ait. American cranberry.—A fine patch fringing the west side of the pond. Charity Island.

Lysimachia terrestris (L.) BSP. Bulb-bearing loosestrife.—Occasional in low grassy places. Noticed in particular about the pond. Charity Island.

Steironema ciliatum (L.) Raf. Fringed loosestrife.—Common in rich woods. Charity Island.

Trientalis americana (Poir.) Pursh. Star-flower.—Common in rich woods. Charity Island.

Fraxinus americana L. White ash.—Frequent in rich ground with other trees. Charity Island.

Fraxinus pennsylvanica Marsh. Red ash.—Frequent in rich ground with other trees. Charity and Little Charity Islands.

Gentiana andrewsii Griseb. Closed gentian.—In damp spots along the beach on the west side. Charity Island.

Menyanthes trifoliata L. Buckbean.—Plentiful in and about the pond. Charity Island.

Apocynum androsaemifolium L. Spreading dogbane.—Occasional in poor ground. Charity Island.

Apocynum cannabinum hypericifolium (Ait.) Gray. Clasping-

leaved dogbane.—Frequent in low ground. Charity and Little Charity Islands.

Asclepias tuberosa L. Butterflyweed.—Occasional in sandy ground. Charity Island.

Asclepias incarnata L. Swamp milkweed.—Frequent in damp places. Charity and Little Charity Islands.

Asclepias syriaca L. Common milkweed.—Frequent on sandy ground, sand ridges, and along the beach. Charity and Little Charity Islands.

Convolvulus sepium L. Hedge bindweed.—Occasional in damp open places and along the beach. Charity and Little Charity Islands.

Lithospermum gmelini (Michx.) Hitchc. Hairy puccoon.—Common in sandy ground, on sand ridges, and in sand along the beach. Charity Island.

Verbena hastata L. Blue vervian.—Occasional in low open places and in damp spots on the beach. Charity Island.

Teucrium canadense L. American germander.—Occasional in damp open places. Charity Island.

Scutellaria lateriflora L. Mad-dog skullcap.—Occasional in low shaded ground. Charity Island.

Scutellaria galericulata L. Hooded willow-herb.—Marsh. skullcap.—Occasional in damp places. Charity Island.

Nepeta cataria L. Catnip.—As a weed about the lighthouse. Charity and Little Charity Islands.

Prunella vulgaris L. Heal all.—Common in damp shaded or open ground. Charity Island.

Stachys palustris L. Marsh woundwort. Hedge nettle.—Occasional in damp open places. Noticed near an old garden at the north end. Charity Island.

Monarda mollis L. Pale wild bergamot.—Frequent on dry sandy ground. Charity Island.

Lycopus uniflorus Michx. Bugle weed.—Occasional in damp shaded places. Charity Island.

Lycopus americanus Muhl. Cut-leaved water hoarhound.—Common in damp places. Charity and Little Charity Islands.

Mentha arvensis canadensis (L.) Briquet. American wild mint.—Frequent in rich open woods. Charity Island.

Solanum dulcamara L. Known in Michigan and western Ontario as nightshade, in England as bittersweet or nightshade.—Common. Charity Island.

Solanum nigrum L. Common nightshade.—Frequent in rich shaded ground. Charity and Little Charity Islands.

Physalis heterophylla Nees. Clammy ground-cherry.—Frequent in dry sandy places. Charity Island.

Verbascum thapsus L. Common mullein.—Occasional along the beach. Charity and Little Charity Islands.

Linaria canadensis (L.) Dumont. Blue toad-flax. Wild toad-flax.—Common in dry sandy ground. Charity Island.

Gerardia pedicularia L. Fern-leaved false foxglove.—Common in dry sandy ground at the south end. Charity Island.

Gerardia virginica (L.) BSP. Smooth false foxglove.—Occasional in shaded sandy ground. Charity Island.

Gerardia paupercula (Gray) Britton. Small-flowered gerardia.—In poor ground on the east side. Charity Island.

Melampyrum lineare Lam. Cow wheat.—Common in shaded dry and sandy ground. Charity Island.

Pedicularis canadensis L. Common lousewort. Wood betony.—Occasional in dry shaded ground. Charity Island.

Phryma leptostachya L. Lopseed.—Frequent in rich woods. Charity Island.

Plantago rugelii Dcne. Rugel's plantain.—A few specimens about the lighthouse. Charity Island.

Galium aparine L. Cleavers. Goose grass.—Frequent in rich shaded ground on Charity Island; abundant on Little Charity Island.

Galium triflorum Michx. Sweet-scented bedstraw.—Common in woods. Charity Island.

Dierrilla lonicera Mill. Bush honeysuckle.—Occasional on poor dry ground. Charity Island.

Lonicera glaucescens Rydb. Douglas' honeysuckle.—Frequent in open woods. Charity Island.

Viburnum lentago L. Nannyberry.—Occasional in woods. Charity and Little Charity Islands.

Sambucus canadensis L. Common elder. Sweet elder.—Occasional in open woods. Charity Island.

Sambucus racemosa L. Red-berried elder.—Occasional in damp woods. Charity and Little Charity Islands.

Campanula rotundifolia L. Harebell. Bluebell. Bluebells of Scotland.—Common on sandy ground and sand ridges, especially near the upper beach. Charity Islands.

Campanula aparinoides Pursh. Marsh bellflower.—In marshy ground about the pond, with the cranberries. Charity Island.

Lobelia spicata Lam. Pale spiked lobelia.—Occasional in open grassy places. Charity Island.

Eupatorium perfoliatum L. Boneset. Thoroughwort.—Frequent in low open places. Charity Island.

Liatris cylindracea Michx. Cylindric blazing star.—In dry sandy ground at the south end of Charity Island.

Solidago caesia L. Blue-stemmed goldenrod.—Frequent in damp woods and thickets. Charity Island.

Solidago hispida Muhl. Hairy goldenrod.—Frequent on sandy ground and sand ridges. Charity Island.

Solidago juncea Ait. Early goldenrod.—Common on dry and sandy ground. Charity Island.

Solidago rugosa Mill. Wrinkled-leaved goldenrod.—Frequent in dry sandy ground. Charity Island.

Solidago nemoralis Ait. Gray goldenrod.—Frequent in sandy ground. Charity Island.

Solidago altissima L. Yellow weed—Common in open ground. Charity Island.

Solidago serotina Ait. Late goldenrod.—Common in open damp places. Charity and Little Charity Islands.

Solidago graminifolia (L.) Salisb. Bushy goldenrod.—Common in damp places. Often in damp sand on the beach. Charity Island.

Aster azureus Lindl. Sky-blue aster.—Common on poor sandy ground. Charity Island.

Aster sagittifolius Wedemeyer. Arrow-leaved aster.—In open woods and places at the north end. Charity Island.

Aster laevis L. Smooth aster.—Common in dry sandy ground. Charity Island.

Aster polyphyllus Willd. Faxon's aster.—Occasional in damp sand along the beach. Charity Island.

Aster tradescanti L. Tradescant's aster.—Frequent in damp open ground. Charity Island.

Aster junceus Ait. Rush aster.—About the pond with the cranberries. Charity Island.

Aster umbellatus Mill. Tall flat-top white aster.—Occasional in damp open woods. Charity Island.

Erigeron philadelphicus L. Philadelphia fleabane. Field daisy.—Occasional in open ground. Charity and Little Charity Islands.

Erigeron annuus L. Sweet scabious.—Occasional in open ground. Charity Island.

Erigeron ramosus (Walt.) BSP. Daisy fleabane.—Occasional in poor open ground. Charity and Little Charity Islands.

Erigeron canadensis L. Horseweed.—As a weed near the lighthouse. Charity and Little Charity Islands.

Antennaria canadensis Greene. Canadian cat's-foot.—Frequent on poor open gound. Charity Island.

Gnaphalium decurrens Ives. Clammy everlasting.—Near the lighthouse on Charity Island in poor ground. Apparently rare.

Rudbeckia hirta L. Yellow daisy. Black-eyed Susan.—Occasional in sandy ground. Charity Island.

Helianthus divaricatus L. Woodland sunflower.—Common in dry open woods. Charity Island.

Helianthus strumosus L. Pale-leaved wood sunflower.—Occasional in open woods. Charity Island.

Bidens frondosa L. Beggar-ticks.—Occasional in damp places along the beach. Charity Island.

Bidens trichosperma tenuiloba (Gray) Britton. Tickseed sunflower. —About the pond with the cranberries. Charity Island.

Achillea millefolium L. Common yarrow.—Frequent. Charity Island.

Artemisia caudata Michx. Tall wormwood.—Common on sandy ridges and in sand along the beach. Charity and Little Charity Islands.

Erechtites hieracifolia (L.) Raf. Fireweed.—Abundant along the beach in damp places. Charity Island.

Arctium minus Bernh. Common burdock.—Frequent. Charity and Little Charity Islands.

Circium lanceolatum (L.) Hill. Common thistle. Bull thistle.—Occasional. Charity and Little Charity Islands.

Circium pitcheri (Torr.) T. & G. Pitcher's thistle.—Frequent in drifting sand along the beach. Charity Island.

Circium muticum Michx. Swamp thistle.—Occasional in marshy places. Charity and Little Charity Islands.

Circium arvense (L.) Scop. Canada thistle.—Occasional. Charity and Little Charity Islands.

Taraxacum offincinale Weber. Common dandelion.—Frequent. Charity and Little Charity Islands.

Sonchus asper (L.) Hill. Spiny-leaved sow thistle.—As a weed near the lighthouse. Charity Island.

Lactuca scariola integrata Gren. & Godr. Prickly lettuce.—As a weed about the lighthouse. Charity and Little Charity Islands.

Lactuca canadensis L. Wild lettuce.—Frequent in open woods. Charity and Little Charity Islands.

Lactuca spicata (Lam.) Hitchc. Tall blue lettuce.—Occasional in damp open woods. Charity and Little Charity Islands.

Prenanthes racemosa Michx. Glaucous white lettuce.—Frequent in damp ground at the south end. Charity Island.

Prenanthes alba L. White lettuce. Rattlesnake root.—Occasional in open woods. Charity Island.

Hieracium venosum L. Rattlesnake-weed. Frequent on poor sandy ground. Charity Island.

Hieracium scabrum Michx. Rough hawkweed.—Frequent in sandy ground. Charity Island.

Hieracium gronovii L. Gronovius' hawkweed.—Occasional in sandy ground. Charity Island.

Hieracium longipilum Torr. Long-bearded hawkweed.—Common on open sandy ground. Charity Island.

Hieracium umbellatum L. Narrow-leaved hawkweed.—Frequent in open sandy ground. Charity Island.

April, 1911.

OUTLINE KEY OF THE GROUPS OF THE GENUS HELIANTHUS IN MICHIGAN.

S. ALEXANDER.

In the summer of 1905 I thought to acquaint myself with the sunflowers which were indigenous in the vicinity of Ann Arbor. On consulting the flora of the state, I found that there were but sixteen species listed for the whole state and one of these was put down as an escape from our gardens. There were not more than six or eight species assigned to the vicinity of Ann Arbor or southeastern Michigan.

It looked as if I should have an easy task. I had not more than begun my work when, to my perplexity, I found plants in great numbers and forms which could not be diagnosed in any of the manuals at my command, including Gray's "Synoptical Flora." I had the pleasure of accepting one of the two following propositions: either I was incapable of diagnosing the plants or that there were many species yet undescribed. After having correctly diagnosed many hundreds of plants during a period of forty-five years I was not disposed to accept the first proposition. I did accept the second and set about to prove it, in which endeavor I traveled over a large stretch of country during a period of five years. During this time I collected a large number of sunflower plants and placed them in a garden where I could study them individually and comparatively. I got as many of the old and well known plants as I could find for purposes of comparison with the new. After five years of study I have concluded that I have found several times as many new plants as have hitherto been known.

The territory of this remarkable development of sunflowers seems to have quite definite limits, and within the general limits some of them are regional. Each of the following rivers, the Clinton, the Rouge, the Huron and the Raisin has a sunflower flora peculiar to itself. The same can be said of the intermediate stretches of country. Some of our naturalists think that these plants are in a plastic, mutating state. I believe rather that they are the remains of a once wonderfully copious genus. The story of this Botanical Terra Incognita would be very interesting and too long to be told here.

I expect to begin a revision of this paper during the present season in which I shall describe and name a large number of plants. The following key extends only to the great and some of the lesser groups. My plants are mostly in the botanical garden of the State University, where I hope our botanists will examine and become acquainted with them.

It will be observed that the first division of the perennial sunflowers into two heads is based on the underground system of each head. It would not be correct to speak of these systems as the root system, since the first head is based on the roots entirely and that in the second

head the roots play no part in its differentiation. The so-called rootstock, or earth branch is the great character there. Hence we will speak of the *underground systems* as bases of fundamental grouping. I think that these systems have never before been used in the classification of these plants.

The genus Helianthus is one of the most interesting and the least understood of all the genera of our Michigan flora. This genus can be arranged under two great divisions, annuals and perennials. As there are no annuals indigenous to Michigan, I shall give them no consideration in this article.

The perennials persist for an indefinitely long time and can be classed under two heads, each containing many lesser groups. These two heads are strongly differentiated and are easily recognized by their different annual growth and methods of vegetative reproduction. In speaking of these heads it is necessary to have names for them, as I shall have occasion to refer to them frequently. I shall therefore, before describing them, give each group a name expressive of its most distinguishing character. The plants of the first head which I shall consider do not move about from place to place by an underground stem or shoot. Being thus permanently located I have named it the Stationary Group. For the reason that the plants of the second head move about annually by means of an underground shoot or runner I have called it the Migratorial Group.

The terms "stationary" and "migratorial" express two remarkably opposite and definitive characters in these groups. But each head has other characters as decidedly opposite and definitive as those above mentioned and strongly demand other names to be used synonymously and interchangeably with those above given. Before going on with these group descriptions, I find it necessary to make a diversion long enough to give consideration to the term "creeping rootstock" which is much used in the manuals in the description of the sunflowers to show the manner of their vegetative perennial perpetuation. The part denominated rootstock in this connection does not fulfill the definitions of the underground shoot of that name as given in the structural botanies, which is: A perennial, horizontally elongated, more or less subterranean, root-like form of the stem, which grows after the manner of ordinary stems, advancing from year to year, by the annual development of a bud at the apex, and emitting roots from the under surface; thus established, the older portions die and decay annually as corresponding additions are made to the opposite extremity. On these root stocks are seen the scars left by the aerial shoots of several years; in the spring the terminal bud unfolds into leaves and flowers, to perish in autumn, a new bud to open in the following spring, and a new internode, with its roots, to abide for several years.

While the foregoing definition applies, in a degree, to the so-called rootstocks of the migratorial sunflowers, it is, in a high degree, inadequate because it contains much more than belongs to the somewhat similar shoot of the plants which we are discussing. It does not apply in any degree to the stationary group as the latter has no shoots at all homologous to a rootstock although the botanists use the term rootstock in their descritions of the very few members of the group which they have known.

Neither does the term rootstock as above defined apply with full force to that underground stem of the migratorial sunflowers which the descriptive botanists call a "creeping rootstock" by means of which the plants of this group are said to be perennial. Rootstocks proper differ from the so-called rootstocks of the sunflowers in the following essentials: The rootstock proper is indefinitely perennial; that of the sunflower is a winter annual vegetatively produced each year and completely dying the next, after having performed its work of the second or functional season as will be more fully discussed further on. The rootstock proper continually adds to its length at the apex by annual growth and dies off to an equal amount at the rear end and bears on its upper surface the scars of the aerial stems of several successive years. The somewhat similar structure in the migratorial sunflower which, in a degree, resembles the rootstock in structure and function, is an underground branch which does not possess several of the essential characters of the rootstock proper as defined in the books.

It resembles the rootstock in having a progressive, forward, horizontal growth for but one season only, and has a terminal bud at the forward end which grows upward during the second season to form the aerial stem with its load of branches, leaves and fruit, and another individual like itself. The resemblance ends here, for, unlike the rootstock proper, it does not possess the following characteristics: It is not perennial, as is generally supposed, or even properly biennial (this statement will be considered infra), hence they do not, after several years growth, die off annually at the rear end to an amount equal to that annually added by progressive growth at the front end, thereby retaining a constancy of length and this for an indefinitely long time; there are no annual stalk scars on its upper surface, indicating the age from the growing point back to the dying end.

It furthermore is not a continuation of the previous year's growth as is the case with the rootstock but grows out from the underground portion of the aerial annual stalk of its own formative season; this makes it a *subterranean branch* identical homologically with the similar structure in the potato and denies to it *all rootstock characters*. Hence the term "creeping rootstock" as applied to the sunflower should be forever discontinued. But we need a special term to be applied to this and identical structures in other plants. A suitable term for this purpose is difficult to find or invent; but I must have some term from now on, and provisionally I shall use the good Anglo-Saxon compound earth-branch. I will cordially thank anyone who will send me a more suitable term for future adoption. This earth-branch has all the characters of a branch, for it buds and branches itself like aerial branches.

I have made a seemingly contradictory statement above to the effect that the earth-branches of the migratorial plants are not perennial as is commonly supposed or even properly biennial This seems the more contradictory when we remember that this group of plants is placed under the classification of perennial.

To reconcile this seeming contradiction I will proceed to give an exact statement of the life history of a single plant. We will begin with the seed, whose young plant as soon as it becomes established the first year, sends out an earth-branch. At the end of the first season

the aerial stalk of the young plant and its roots die, and thus completely sever the connection between the young parent plant and the earth-branch. The latter being left perfectly independent, lies dormant until the following spring when the terminal bud grows upward into the aerial stalk of the season, at which time the earth-branch ceases to be such, but develops its rootlets of last year's formation into large roots, and functions itself as such, changing from a succulent to a hard woody texture.

After the aerial stalk is established it sends forward new earth-branches as did the parent seedling of the previous year, and in the prolongation of last year's growth. These earth-branches branch more or less, each branch diverging somewhat, but tending to grow parallel with the main branch of the last year's growth. At the end of the season the aerial stalk and its roots all die as did the seedling plant the year before, thus completely severing all living connections with the new earth-branches, which are left independent to repeat the process just described the next year and on indefinitely. This is the life history of a single plant.

It must now be evident why I have designated this group of sunflowers as migratorial. It is by this character that they spread by underground growth. It will be seen from the foregoing that an earth-branch has two seasons duration, less than a year and a half in all; or from the first of May until the last of October of the next year is the term of their life. This is the reason why I have said tnat they are not perennial or properly biennial. The first season of their existence I have designated as their formative season, during which they perform no other work than that of growth and preparation for the second or functional season, during which they produce from their terminal buds the aerial stalks of that season and the earth-branch for the following year's work.

Each year's plants leave behind them lines of dead annual ancestors, each one of which was produced vegetatively by its annual parent of the previous year. Each plant lives a sort of double life, while dying from age and exhaustion, they are renewing their youth by producing from their own bodies a young plant in the shape of an earth-branch which will function next year and die. The old plant and the new, parent and offspring, age and youth, death and revival are all in one plant at one time.

Having shown very marked differences between the rootstock proper and the so-called rootstock of the migratorial sunflowers. I will now return to and proceed with the extended description of each of the great perennial divisions of the genus under consideration.

The group which I have described as stationary is such for the reason that each plant has a perennial crown which annually produces buds just at the surface of the earth and around the present year's stem which dies down to the ground each autumn. The succeeding spring these buds grow and become the aerial stalks and stems of that season. Hitherto botanists have described these plants as being perennial by "thickened fleshy roots and creeping rootstocks." I will here repeat that they have no rootstocks or anything corresponding to them. Unlike the migratorial plants they have *nothing underground but roots.* By means of the roots this section of the sunflowers is divisible into two diverse

groups. The first group has very much thickened, fleshy roots, in allusion to which I have called it the Carnosae, or fleshy-rooted group. The second group has fibrous roots, for which reason I have called it the Fibrosae. Right here comes in another remarkable distinction between these groups The roots of the Carnosae, for example those of *Helianthus giganteus*, have hitherto been considered as perennial, a notion which I had accepted up to June, 1911, but this is entirely erroneous. The crown of this group is perennial, but the roots are winter annuals. They are formed each year anew by the perennial crown and function as roots only *during their first or formative season*. During the latter part of that season they become thick and fleshy by the deposition of much reserve material which is entirely consumed the next spring by the crown in the formation of new roots and the aerial stalks. Thus it will be seen that the roots, *as roots* have but one season's existence, for during the second season they do not function as roots to any extent whatever, but simply as repositories of food for the new growth. The Fibrosae, chiefly a new group, are very different. The roots of this group are perennial. I will not say more about this group until after I have given it another season's study.

Sometimes the stems which grow from the lower buds of the crown of these plants, when obstructed in their upward growth by superposed roots will work their way for a short distance under ground until they find an opportunity to take an upward course and emerge from the ground. At the point of emergence a fascicle of roots will be formed similar to that of the parent. The roots of these plants sometimes bud on the thickened part and send up an aerial stem which will form a new fascicle of roots. It is a characteristic of some of the species of this group that, if earth be piled high around the base of the stalks a new fascicle of roots will be produced above the old one. This is not the case with the migratorial group.

Because of the fact that several stalks arise each year from the buds of the crown, and also that each stalk may and frequently does send out new roots, the plants are clustered or caespitose. The ground around these clusters is packed full of these roots. In many of the Fibrosae the roots are interwoven and thickly matted. This is a general character of the whole group which distinguishes it very decidedly from the migratorial group.

The technical name of the group I have therefore called Storeatae, which is derived from the Latin *storea*, a mat. The Storeatae, sub-group Carnosae, falls into two sections, as follows:

Section 1. The Pinnatae, or plants whose leaves are pinnately veined. This section embraces the following old and well known plants besides several other species recently found in this state by the author. Their description will be given in the revision of the monograph.

Section 2. The Trinervae, whose leaves are three-nerved after the manner of those of the great migratorial group which will be considered farther on.

This is a large and very remarkable group of plants all of whose species now known were discovered by the author within the last four years chiefly during the autumn of 1910. It will thus be seen that this section is new to science. It divides itself into two well marked sub-sections in the following manner: *Asperae* which consists of plants

whose stems and leaves are rough to very rough. This group consists of a large number of species of various aspects and habitats. The second sub-section of the Trinervae I have called the *Planae*. This group, as its name implies, consists of plants whose stalks are glassy, smooth and generally glaucus, and are variuos in inflorescence and form of leaf.

The second great head of our perennial sunflowers I have called the Sparsae, a name indicative of the scattered condition of the underground system. The roots in this group are few and small and are of but slight descriptive importance. The two great distinctive characters in this very natural assemblage of plants are its earth-branch and through that the migratorial habit. This head resolves itself into smaller groups in the following manner: Nonpetiolae or sessile leaved group, which is further divided into the Uninervae, whose leaves are narrow and strictly one-nerved and contains the following old species of other states put in here to complete the classification:
H. angustifolius L., H. orgyalis DC.

The leaves of the second group of the Nonpetiolae are all three-nerved, for which reason I have called it the Triplinervae. Among the old and well known species which belong in this group are the following Migratorialae:

H. divaricatus L.
H. mollis Lam.
H. doronicoides Lam.
H. ciliaris DC.
H. radula Torr. & Gray.
H. heterophyllus Nutt.
H. cinereus Torr. & Gray.

There is but one of the above species indigenous to the state. I have put the foreign plants in to complete the sequence of groups. I have several more newly discovered three-nerved sessile-leaved plants of this state in the Botanical garden not yet described.

The second group of the Sparsae consists of those plants which are manifestly petioled. I have named this group the Petiolae. This is a large assemblage of plants and consists of both old and new species, the latter far outnumbering the former. It is composed of two sub-groups namely: Earth-branch cylindrical or the Cylindrae, which is still further divided into the Nudipetiolae consisting of plants with leaves whose petioles are nearly or entirely wingless. This is not a very large group, perhaps from ten to fifteen species, all but one of which are new to science and indigenous to the state.

The second section of the Spargerae consists of plants whose leaves have petioles conspicuously winged and contains the great bulk of the genus Helianthus. It is called the Alatae. There are about twelve or fifteen old species belonging to this section. Conspicuous among these, strumosus, decapetalus and occidentalis may be given as representative examples. It seems very remarkable that the winged petioles should never before have been used as group characters. This character I find highly useful in differentiating groups and species.

The second group of the Petiolae is made up of plants whose earth-branches bear terminal tubers. The H. tuberosus may be taken as the

type of this group. The latter species has never been reported as indigenous to this state by any of the writers of catalogues of the state flora, although it grows abundantly in and around Ann Arbor, the Agricultural College, along the banks of the Huron River and also along the banks of the Rouge River in and far above Detroit. The typical H. tuberosus was reported by Winchell in his catalogue of 1860 and quoted by others as the H. hirsutus, the latter being a plant without winged petioles or tubers and I doubt that it is indigenous to the state. Instead of there being one species of the tuber bearing sunflowers and one or two so-called varieties, there is a large number of species of various aspects, habits and habitat. The several species vary in height from two to twelve feet, from smooth to very rough pubescent, and each species bears tubers very characteristic of itself. The earth-branches vary in length from two to five feet. This division of the Petiolae in contradistinction from the Cylindrae I have named the Tuberae. Although I have named many of the species in this group, I have neither subgrouped nor described them and shall not or cannot do so until the proper season arrives.

COMPARATIVE SYNOPSIS OF THE TWO GREAT DIVISIONS OF THE PERENNIAL SUNFLOWERS OF MICHIGAN.

Plants stationary.	Plants migratorial by a progressive underground growth, the earth-branch.
Plants properly perennial by a perennial crown.	Perennial by a succession of winter annuals, each of which is produced vegetatively by the previous year's plant.
Crown producing surface buds from which arise the aerial stalks of the next year.	No crown, and hence no surface buds from which next year's aerial stalks arise.
Roots fascicled, fleshy or fibrous, hence Storeatae from the Latin *storea*, a mat.	Roots not fascicled, or fleshy, or perennial, or matted, but few, scattered.
Roots· (Group Carnosae) fleshy, formed each year anew by the perennial crown and completely consumed the next by the same crown to form new roots and stalks. (Group Fibrosae) fibrous, perennial and hence not consumed by the crown.	Roots are annual and hence they do not maintain a living, perennial connection with a crown, since there is none, and through that with each other. The roots instead of being an outgrowth from a perennial crown, arise from the annual earth-branch.
No rootstock, or any growth which is in any degree homologous to that form of underground stem, notwithstanding the fact that manual writers use the term "creeping rootstock" in the description of their plants.	The earth-branch has two seasons of life, viz., the first, or formative season, during which it does no work but to come forth and perfect itself for the work of the second, or functional season, during which it produces an organ like itself, and then by death completely severs its connection with its vegetative offspring, which becomes next years plant. The above p.ocess is repeated for an indefinitely long time.

TABULAR SYNOPSIS OF SUNFLOWERS.

- Perennial..
  - Storeatae .
    - Carnosae . .
      - Pinnatae . .
        - Scabrae e. g.
          - H. giganteus.
          - H. Maximiliani.
        - Glabrae e. g..
          - H. Kellermani.
          - H. grosseserratus.
      - Trinervae...
        - Asperae.
        - Planae.
    - Fibrosae (Not yet well enough studied for subdivision).
  - Sparsae..
    - Cylindricae . .
      - Petiolae . .
        - Nudipetiolae.
        - Alatae e. g. . .
          - H. decapetalus.
          - H. stromosus.
      - Nonpetiolae.
        - Uninervae e. g. H. angustifolius.
        - Triplinervae e. g. H. divaricatus.
    - Tuberae e. g. H. tuberosus.

To the Michigan botanists I need make no apology for the incompleteness of the foregoing sketch for it was in response to their earnest solicitations that I have made this outline statement so that they could in the future, in case of my disability, carry the work to completion.

EXPLANATION OF ACCOMPANYING CUTS.

Cuts No. 1 and No. 2 represent two distinct forms of the Storeatae. The roots of No. 1 are fibrous while those of No. 2 are thick and fleshy with long attenuations.

Cuts Nos. 3, 4 and 5 represent earth branches of the Spargerae. They are shown here at the beginning of their second or functional season. It will be seen that they have no roots except some very small ones at the apices. The small ones would develop later into large roots. No. 3 is natural size. No. 4 is two-thirds natural size. In No. 4 the old plant of last year shown in the right-hand upper corner is completely dead.

These five cuts represent in a general way the more prominent underground systems of the genus. The other forms are modifications of these.

Detroit, Mich., July, 1911.

A RETROGRESSIVE METAMORPHOSIS ARTIFICIALLY PRODUCED.

S. ALEXANDER.

If fairly matured blossom buds of the peach be inserted in a stock after the way of ordinary bud grafting, they will generally drop off without making any growth, but occasionally they will grow after the following manner:

The peduncle will increase in length to the extent of five or six inches. The sepals will grow to the size and length of full-sized leaves. The petals become sepal-like and the stamens take on color, expand their filaments and appear like petals. The styles and stigmas divide to an extent and endeavor to become stamens but fail.

If these retrogressed flowers be permitted to further develop they will send out a bud which will grow into a tree.

I have witnessed this phenomenon a number of times—from twenty to thirty in all—in my own peach nursery.

Detroit, Mich., April, 1911.

Fig 1.

Fig 2.

Fig. 3.

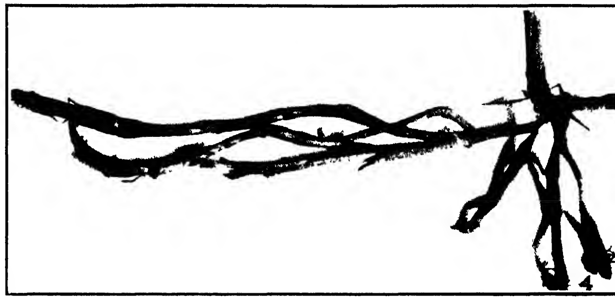


Fig. 4.

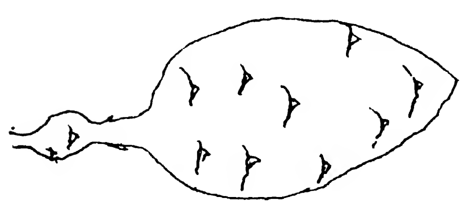


Fig. 5.

PSYCHOTRIA UNDATA AS A COFFEE PLANT.

ERNST A. BESSEY.

The seeds of *Psychotria undata*, a native of Southern Florida, when dried and parched give off the odor of roasting coffee. When ground and boiled in water a solution with the odor and taste of coffee resulted.

THE HAMMOCKS AND EVERGLADES OF SOUTHERN FLORIDA.

ERNST A. BESSEY.

Hammocks are dense formations of broad-leaved evergreen trees occurring in the midst of the dry, very open pine forests. The latter are often semi-xerophytic in nature while the hammocks are very moist with a great abundance of epiphytes. The plants of the hammocks are much more tropical in general than those of the pine woods. The hammocks apparently modify their immediate environment by increasing the humidity of the air and thus favor their slow spread.

The everglades are nearly level prairies, submerged for most of the year and accordingly treeless except in the higher places where submergence does not occur or is less prolonged. The vegetation is largely Monocotyledonous. It is less tropical than that of any other formation of Southern Florida, probably owing to the greater radiation and lack of protection which permits the temperature to drop quite low occasionally.

East Lansing, Mich., April, 1911.

CONDITIONS WHICH AFFECT THE BRANCHING OF ROOTS.

LULU M. NEWLON.

It is a well-known fact that when a root is injured at its tip, so that apical growth can no longer continue, its production of lateral roots is increased. Roots commonly produce lateral branches, however, while their tips are still uninjured and growing. The aerial roots of Philodendron and vanilla, and the stilt roots of Indian corn, when uninjured, do not produce branches while growing in the air, but after entering the soil they branch freely. Pond, in his experiments with Ranunculus aquatilis, has shown that light inhibits the growth of lateral roots.

These observations have led to some speculation concerning the conditions which affect the branching of roots in different plants. Accordingly, experiments have been carried on by the writer, under the direction of Professor F. C. Newcombe, since October, 1910, and are still in progress for the purpose of determining the nature of these conditions.

The plants which have, thus far, been used, are Elodea canadensis, Proserpinaca palustris, Ranunculus aquatilis, Radicula nasturtium-aquaticum, Ludvigia palustris, Bryophyllum calcynum, Tradescantia zegrina, Zea mays and Salix nigra. Experiments have also been begun with the roots of Philodendron giganteum and Vanilla planifolia, but so recently that nothing has yet been attained.

The above plants were chosen for this work, some, because their roots were known not to branch under certain conditions, others, because roots could be easily obtained from them; also, these plants furnish examples of soil, aquatic and aerial roots.

From the experiments which have thus far, been carried on it has been found (1) that in none of the above plants does contact act as a stimulus for the production of lateral roots, (2) that in all the plants used, except Elodea canadensis, lateral roots are freely produced in soil, (3) that in the aquatic and semi-aquatic plants used, (except Elodea), light inhibits the growth of lateral roots, (4) that in the terrestrial plants used, lateral branching of roots takes place with equal freedom in light and in darkness, when the roots are under water.

University of Michigan, April 20, 1911.

LIGHT AS A FACTOR INDUCING PLANT SUCCESSION.

FRANK C. GATES.

Everyone has noticed that in the dense shade of some trees no blue-grass will grow. That the most potent factor involved is light is shown

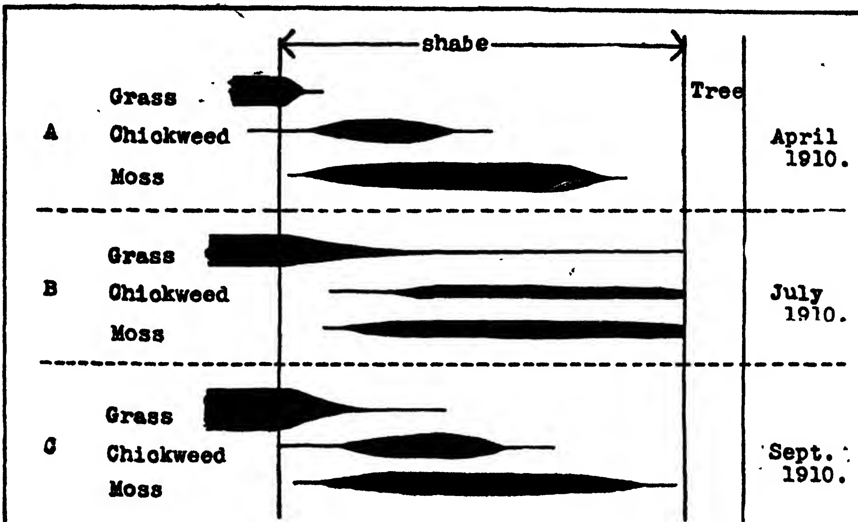


Diagram showing the successiv relationships of the vegetation under a basswood tree during the season of 1910.

by the following observations made in Graceland Cemetery, Chicago, from 1904 to 1910. If lack of sufficient light is the cause for the absence of bluegrass, then readmittance of light—other things being equal—ought to be followed by the reappearance of bluegrass. How short may be the time involved is shown in this instance under observation.

In 1904 the ground around a large basswood tree (*Tilia americana*) was sodded clear up to the trunk. The low widely spreading limbs were, however, left untrimmed. They shaded the ground very densely for a radius of about three meters. Although the bluegrass was abundantly furnished with every necessity except light, as time went on, the bluegrass began to die out around the trunk. Moss soon developed in the area left bare of bluegrass. At the beginning of the season of 1910 the moss occupied a ring about 1.5 meters in width beginning where the bluegrass left off and extending to one-half to one-quarter of a meter of the tree trunk. There were a few other plants growing in the moss of

which chickweed (*Stellaria media*) was most abundant. The relative distribution of these plants is shown at "A" in the accompanying diagram.

The spring of 1910 set in unusually early and by the end of the second third of April virtually all the trees had leaved out. The last third of April was ushered in by heavy wet snows and continued freezing weather. This resulted in the virtually complete defoliation of the basswood and consequent readmittance of light to the ground below. The basswood did not become refoliated until late in July. Meanwhile great changes were taking place on the ground beneath. Within a month the bluegrass had reinvaded not only the moss ring but also the bare ground at the base of the tree. It was quite well established before the leaves reappeared on the basswood. The amount of moss and chickweed was noticeably diminished. Their zones were quite evidently retreating. This condition of distribution is shown at "B" on the accompanying diagram.

When the basswood regained its leaves conditions were changed again. The bluegrass which had regained its lost ground was again vanquished. This was, however, not entirely completed during the growing season of 1910. The bluegrass was entirely driven out from the immediate vicinity of the tree trunk but not entirely out of the moss ring, as is shown at "C" in the diagram.

This gives an idea of how rapidly invasion may take place beyond a tension line—such the boundary between sufficient and insufficient light—when the factor which causes it is decidedly changed. It leads to the conclusion that when one factor is varying the time of invasion is relatively much shorter than the time of retreat.

University of Michigan, April 20, 1911.

THE ORCHID FLORA OF THE VICINITY OF BATTLE CREEK.

C. C. MC. DERMID.

(Names according to Gray's New Manual.)

1. Corallorhiza trifida. Rare.
2. Corallorhiza maculata. Common.
3. Cypripedium acaule. Plentiful.
4. Cypripedium hirsutum. Rather common.
5. Cypripedium parviflorum. Rather common.
6. Cypripedium parviflorum var. pubescens. Rather common.
7. Cypripedium candidum. Rare.
8. Habenaria bracteata. Rather common.
9. Habenaria lacera. Common.
10. Habenaria leucophaea. Rather rare.
11. Habenaria ciliaris. Common.
12. Habenaria ciliaris x H. leucophaea. Rare.
13. Habenaria Hookeri. Infrequent.

14. Habenaria dilatata. Frequent.
15. Habenaria psychodes. Frequent.
16. Habenaria clavaria clavellata. Frequent.
17. Habenaria hyperborea. Infrequent.
18. Habenaria flava. Infrequent.
19. Orchis spectabilis. Very rare.
20. Pogonia ophioglossodies. Common.
21. Pogonia verticillata. Plentiful locally.
22. Calopogon pulchellus. Frequent.
23. Arethusa bulbosa. Very rare.
24. Liparis Loeselli. Common.
25. Spiranthes cernua. Common.
26. Spiranthes gracilis. Less common.
27. Goodyera pubescens. Frequent.

All the orchids in the above list I have recently found within a radius of one and a-half miles, northeast of Battle Creek. Twenty of them occur—some very rarely—in the immediate vicinity of a single lake a few acres in extent, a considerable marsh-rim too wet to be overrun by fire or to be pastured, sheltering the greatest number; and two species of Spiranthes appear at the junction of upland and marsh. The Larger Coral-root, Larger Yellow Ladyslipper, Rattlesnake Plantain and Hooker's Orchid occur on the wooded hillside partly enclosing the lake basin. It is a veritable orchid paradise, especially to one who has the patience to hunt the proverbial "needle in the hay stack;" but I am dreading the day when ruthless "improvement" shall make it to the flower lover a barren waste.

In addition to the above list, members of the Battle Creek Nature Club have also found not far from home the following:

28. Aplectrum hyemale.
29. Liparie liliifolia.
30. Habenaria orbiculata.
31. Spiranthes lucida.

But I have not yet seen these myself in my limited range.

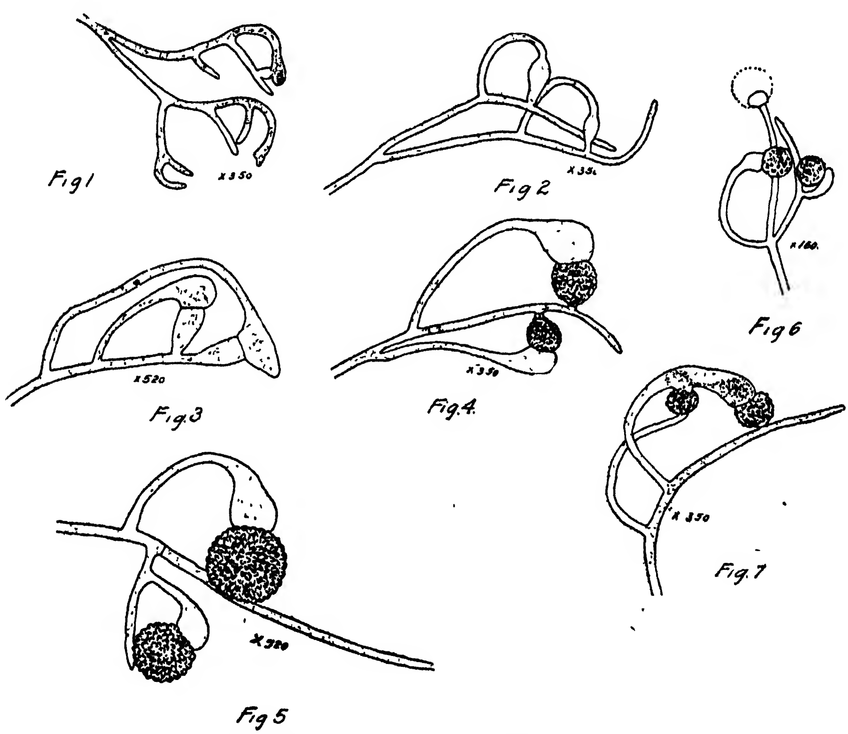
Battle Creek, April 3, 1911.

THE OCCURRENCE OF ZYGORHYNCHUS MOELLERI IN MICHIGAN.

H. GROSSMAN.

In the year 1886 P. Vuillemin described a new species of Mucor to which he gave the name of Mucor heterogamus. He called it heterogamus because unlike most of the Mucor species, the zygospore is formed

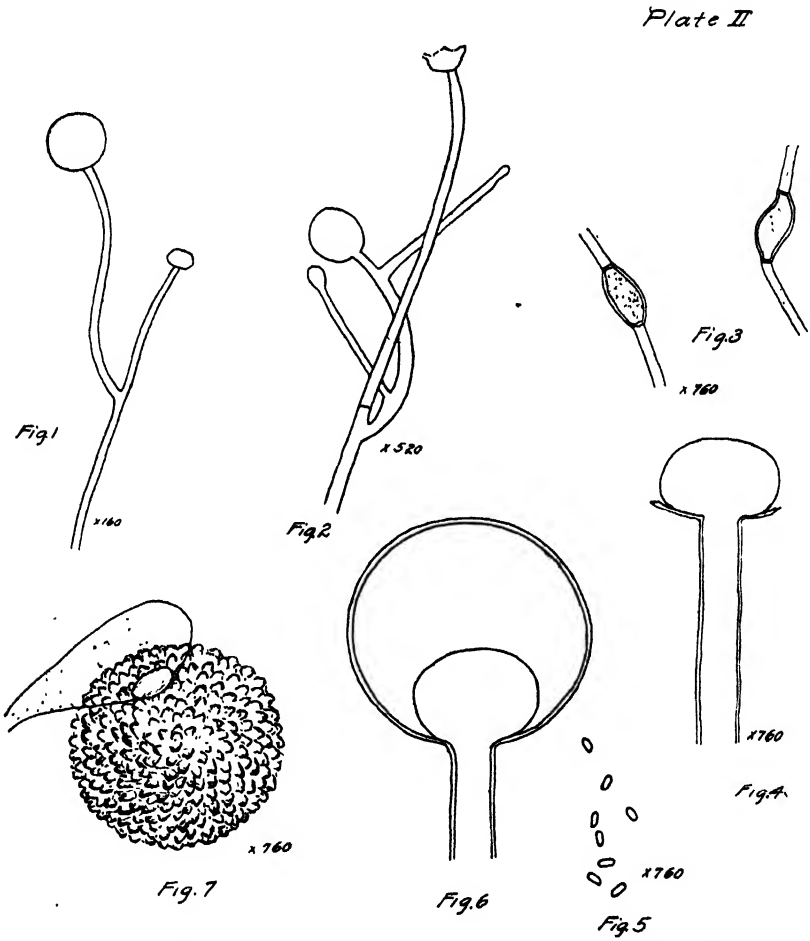
Plate I



ZYGORHYNCHUS MOELLERI. DEVELOPMENT OF ZYGOSPORES.

by the union of two so-called copulating branches, which are unlike both in shape and size. These copulating branches are formed in the following manner: At the end of the main branch, or in some cases, of the side branches of the fungus mycelium a cross wall was formed; that portion of the end which is cut off, however, continuing to grow in length but remaining thin and slender. Just in back of the cross wall, a side

branch is formed which grows upward and arches over towards the thin slender branch. Vuillemin calls this arched branch the female copulating branch. Towards it a short stump-like branch grows from the slender branch. The zygospore is formed from a part of the female branch. After the copulation a new branch grows out from the female branch which in turn forms new copulating branches and eventually zygospores. This is repeated several times until a sympodially branched



ZYGORHYNCHUS MOELLERI, SPORANGIA, ZYGOSPORE AND CHLAMYDOSPORE.

zygospore carrier is formed with several zygospores which are situated on the ends of arched branchlets.

Dr. A. Fisher suggested that the difference in size and shape of the two copulating branches and the formation of the zygospores on upright sympodial branched zygospores carriers are characters of such importance as to justify the making of a new genus for this form. A similar heterogamus copulation is noticed in the genus Dichranophora as pointed out by Schröter.

This suggestion was given further attention by P. Vuillemin who, in 1903, published a paper entitled: "Importance taxinomique de Pappareil zygospore des Mucorineen." In this paper he gives a new classification of the Mucorales, laying great stress upon the manner in which the zygospore is formed in the different genera and using the method of zygospore formation as a distinguishing character in determining genera and even families.

In his new classification he makes a new sub-family, namely, Zygorhynchees. Under this is included Dichanphora and Zygorhynchus heterogamus, formerly Mucor heterogamus, and also a new species Zygorhynchus Moelleri. It is especially with this last form that this paper is concerned.

In 1902 Prof. A. Moeller of Eberswalde found a species of Zygorhynchus very similar to Zygorhynchus heterogamus, but which differed from it in some important characteristics, namely in the shape of the sporangia spores, the columella, and in the size of the zygospores, as well as in few miner differences. The fungus was reported to the Society of Mycology of France, and it was decided that the differences determined by Moeller were significant enough to warrant calling the form which he found a new species and accordingly it was called Zygorhynchus Molleri after its distinguished discoverer.

It was while identifying the various kinds of soil fungi in soil samples taken in Ann Arbor that a specimen of Zygorhynchus Moelleri was found. Because of the peculiar formation of the zygospore, it immediately attracted attention and a study with regard to its technical description and drawings seen in the accompanying plates were made.

The fungus was grown on a culture medium of the following composition:

Primary potassium orthophosphate, KH_2PO_4 $\frac{\text{mol. wt.}}{100}$

Calcium nitrate..................$Ca\,(NO_3)_2$ $\frac{\text{mol. wt.}}{100}$

Magnesium sulphate.................$MgSO_4$ $\frac{\text{mol. wt.}}{1000}$

Cane sugar............. ....$C_6H_{22}O_5$ $\frac{\text{mol. wt.}}{100}$

Agar 2 % or gelatin 30%.
One litre of distilled water.

It was also grown on a very rich medium containing beef extract and gelatin. In both cases it formed immense numbers of zygospores with only a limited number of sporangia. The former medium seemed to accelerate fruitification and to inhibit to a certain extent the growth of the vegetative mycelium. This was probably due to the poor culture medium. At ordinary temperatures, 68° to 75° F., zygospores were formed in as short a period as three days from the time of inoculation.

The description of the fungus as grown on the agar medium is as follows: Sporangiophores upright 1 to 1.5 mm. long and 10 microns broad, usually simple, or in some cases branched once and in others very irregularly and profusely branched. Sporangia are 60-70 microns in diameter, round, deliquescent, spiny, the sporania on the main axis ripening first in those cases where the sporangiophore is branched. Columella smooth, of a suppressed spheroid shape, 28-38 microns long and 23-36 microns broad. Spores light green in color, elliptical, 3.3 microns long and 2 microns broad.

Zygospores sometimes formed on sporangiophores, but more often on special upright sympodial branching carriers which project above the substratum. The zygospores are round 30-60 microns in diameter and dark brown in color. The exospore is covered with numerous warts, and is almost black in color; the endospore also having warts but being light brown in color.

Gemmae intercallary, usually formed on short, thin sympodially branching side branches; at first elliptical, but later rounding up somewhat and becoming thick walled. The size varies in length from 8-13 microns and in width from 13-23 microns.

The formation of the zygospore is probably best described by referring to the accompanying plates. Figure I, Plate I, shows a common method of branching of the mycelium just before zygospore formation. It will be seen that the mycelium branches at its tip, one branch being a continuation along the axis of the mycelium while the other projects upward and arches over toward it. The arching continues until the curved branch touches the other one when the walls at the point of contact are dissolved away and a complete passage way is formed between the two branches as shown in Figs. 1 and 2, Plate I. Figure 3 shows the part which is to become the zygospore cut off from the copulating branches. The time of this cutting off is very variable, taking place in some cases when the zygospore is extremely young and in others only after the zygospore has taken on the warty character. Figure 7 shows an interesting variation in which two zygospores are formed from the same large copulating filament. Figure 7, plate 2, shows a mature zygospore with its characteristic tympanum-like spot where the larger copulating branch is attached to the zygospore. Under favorable conditions a small round spot may be seen where the smaller copulatory branch is attached to the zygospore. The method of the branching of the sporangiophore is shown in Figure 1, plate 2, while figure 3 shows the gemmae much enlarged. The characteristic shape of the spores is shown in figure 5, and figure 6 shows a sporangium much enlarged with the columella in place.

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University of Michigan, April 20, 1911.

SOIL FUNGI.

A PRELIMINARY REPORT OF FUNGI FOUND IN AGRICULTURAL SOIL.*

H. N. GODDARD.

INTRODUCTION.

It is well known that a great amount of work has been done in recent years, on the bacteria of the soil, and their importance is recognized. However, comparatively little attention has been given to soil fungi, and little is known of their influence on plant growth.

This investigation was begun about a year ago, in the botanical laboratory of the University of Michigan, under the direction of Prof. J. B. Pollock. The purposes especially in view were the following: First, to determine what species of fungi live habitually in an ordinary agricultural soil; second, to ascertain their distribution as to depth and kinds of soil, and third, to find what part they take in soil fertility.

A plat of rather rich clay loam, having a liberal amount of sand, was chosen for investigation. Samples of this soil were taken and cultures made in the laboratory by the usual plating method. From these, pure cultures were isolated and studied.

CULTURE MEDIUM.

The medium selected for the platings was chosen largely with reference to the idea of inhibiting the growth of bacteria, which would seriously interfere with the study of the fungi. For this purpose, two methods were tried. First, a large per cent of gelatin was added to the medium; and second, the medium was made strongly acid by the use of oxalic or lactic acid. The latter method was largely a failure and was abandoned on account of the frequent liquefaction of the medium after addition of the acid. The first method was fairly successful, and was therefore employed, throughout the investigation. The only difficulty in its use, was a tendency with the salts used, to get a precipitate during the sterilization. This occurred much less by three successive sterilizations in an ordinary steam sterilizer, than in an autoclave. By the former method it was possible to get a fairly clear medium which worked well. Practically no bacterial growth was observed upon it. The full composition of this medium was as follows:

Gelatin	30.0%
Agar	2.0%
Monopotassium phosphate	0.2%
Ammonium nitrate	0.2%
Magnesium sulphate	0.02%

The acidity of this medium was tested by the method in common use among bacteriologists, described by Dugger (1) in his recent book. This

*Contribution No. 128 from the Botanical Department of the University of Michigan.

gave an acidity of 80+, according to Fuller's (1) scale. The inhibiting effect on bacterial growth appeared to be due to this rather strong acid quality.

METHOD OF SAMPLES, PLATINGS AND ISOLATIONS.

The method of taking the soil samples, was a modification of that used by King, at the Kansas Agricultural Experiment Station, in bacteriological work. The sampler and other instruments were sterilized over an alcohol flame, immediately before use each time. Samples of 2 c.c. each, were taken and transferred to sterile, cotton-stoppered test tubes, which were then taken to the laboratory and each treated with 18 c.c. of sterile, distilled water. After thorough shaking, 3 drops were transferred from each by means of sterilized pipettes, to the first of a series of three tubes, each containing 10 c.c. of the nutrient medium. From the first tube, 3 drops were transferred to the second and from the second, 3 drops to the third. Plates were then poured in the usual way. Vigorous growth was generally obtained in from three to four days. When individual mycelia were distinguishable, pure cultures were isolated to culture tubes. An agar medium, similar in composition, but without the gelatin, was usually employed for these pure cultures, since the gelatin medium was found to liquefy easily, especially in warm weather. Little difficulty was encountered in getting pure cultures in this way. That the method of plating was successful in keeping out all foreign spores, was demonstrated by a set of blanks, which was made at the time the other plates were poured. These were poured like the others, but were inoculated from sterile, distilled water. On these no fungi developed until many days after liberal growth had occurred on the soil inoculated plates, and then, only an occasional mycelium appeared on the very edge of the plate. In most cases, these blanks were perfectly clear for weeks after their preparation.

PROBLEMS OF STUDY.

As suggested in the introduction, these fungi were now investigated with reference to the following problems:

1. Distribution as to depth.
2. Distribution as to kind and treatment of soil.
3. Structural characters and identification.
4. Power to assimilate atmospheric nitrogen.

It is the purpose of this paper to present a preliminary report on the first three of these only. The fourth will be reserved wholly for a later publication, in which the results of the entire investigation will be presented in final form.

DISTRIBUTION AS TO DEPTH.

The plat selected for experiment, was a piece of garden soil, which had been in use for many years for raising common vegetables, usually in rotation. It had been heavily manured as a rule, but during the last three or four seasons, this had been less frequent and less abundant. No manure had been used the year preceding the investigation, although a

garden crop had been raised. The entire plat was 20x60 feet. This was divided into three equal squares, which were treated as follows:

Plat I, was untilled and unfertilized.

Plat II, tilled but unfertilized.

Plat III, both well tilled and well fertilized with manure.

This is graphically shown by the following chart:

Plat I. Untilled and unfertilized.	Plat II. Tilled and unfertilized.	Plat III. Tilled and fertilized with manure.

The studies of distribution according to depth, were made on all of these plats. Samples were taken in duplicate, and in different positions on each plat. Three depths were tried at first; viz., 2 cm., 8 cm. and 14 cm. The following table indicates the samples taken with the dates of the different series:

Date.	Plat.	Number of samples.	Depths in cm.
April 28	I	2 series in duplicate	2, 8, 14
July 12	I	2 series in duplicate	2, 8, 14
July 12	II	2 series in duplicate	2, 8, 14
August 15	III	1 series in duplicate.	4, 12
October 12	I	1 series in duplicate.	4, 12
October 12	II	1 series in duplicate	4, 12
October 12	III	1 series in duplicate	4, 12

A series in duplicate, indicates a set consisting of two samples at each level given, the duplicates being taken at the same level as near as possible at the same spot, perhaps an inch or two apart.

When mycelia had become 3-5 cm. in diameter, countings were made of the number in each plate, as accurately as possible without special device. A summary of a tabulation of these data is here given.

Plat.	Average number of mycelia at each depth.				
	2 cm.	4 cm.	8 cm.	12 cm.	14 cm.
Plat I	68 6	21 5	52 3	29 0	54 3
Plat II	101 5	32 5	59 5	35 5	50 0
Plat III	17 8	36 0		28 0	20.0
Average for three	62 3	30 0	55 9	30 8	41.4

It is believed that while the absolute value of these data is not perhaps great, nevertheless their relative values are significant. The method of counting was of course not perfectly accurate. Moreover, the limited number of samples and the difference in the times of taking them, might easily affect the absolute results. Still, the comparative results indicate strongly that fungi are quite uniformly distributed at different depths in the soil, at least as low as 14 centimeters. No samples were taken at a greater depth.

The results showed further, that depth was not an important factor in the location of particular fungi. Practically all the species were found at all the depths tried, and not in conspicuously larger numbers at one than another. This may be illustrated by giving the data on this point for the two most abundant species; viz., *Fusarium-Cephalosporium* and *Mucor (species?)*.

Name.	Number of cultures obtained at each depth.				
	2 cm	4 cm.	8 cm	12 cm	14 cm.
Fusarium	2	1	5	3	2
Mucor	4	3	1	3	3

DISTRIBUTION ACCORDING TO TREATMENT OF THE SOIL.

As seen from the preceding chart, the three plats were differently treated as to tillage and fertilization. It was expected that a marked difference would be found in the flora of the different plats, especially in Plat III, which was heavily manured and then well spaded and raked. However, the results did not seem to sustain such an expectation. Out of about sixty pure cultures isolated, representing eighteen different species, but two species were found exclusively on Plat III, while three were found only on plat I, and three on plat II. It would seem rather more reasonable to suppose that these differences were due, rather to the chances of sampling or isolation, than to differences in the plats. The results therefore, while perhaps not perfectly conclusive, do point to the conclusion, that there is a rather constant and characteristic fungous flora in the soil, regardless of the treatment as to tillage or fertilization. It should be noted in this connection, that the samples from the manured plat were not taken until about three months after the manure was applied. Any fungi therefore, which might have been introduced with the manure, may have begun to grow, and finding conditions unfavorable, may have died out. However, it is recognized that the results are open to the criticism, that comparatively few samples were taken, and also that only relatively few of the fungi actually in the samples, were isolated. While this is true, nevertheless, I believe that few of the species actually present, were missed in the isolations.

The idea of a fairly characteristic fungous soil flora is emphatically confirmed by the results of Mr. Grossman, who working in the same laboratory, with a very different soil, found eight of the species here given, out of a total of about twelve isolated. His isolations were made

from a very fine, pure clay, on which plants grow poorly, located about a mile from the plat used in this investigation. It may be added further, that five species in the list here given, are the same as those reported by Oudemans and Koning (4) in 1901, found in a forest soil near Amsterdam, Holland.

NAMES AND STRUCTURAL CHARACTERS.

The following is the complete list of fungi found, so far as they have been identified at the present time. The list is not believed to contain all the species present in the soil studied. Probably many others could be isolated by further study.

PHYCOMYCETES.

Mucor (species?)

HYPHOMYCETES.

*Myceliophthora (species?) Cost.
Coccospora (species?) Wallr.
*Fusarium-Cephalosporium (species?) Link-Corda.
**Acrostalagmus cinnabarinus Corda.
*Pachybasium hematum (Bonord).
**Aspergillus calyptratus Oudem.
**Aspergillus nidulans Eidam.
**Aspergillus glaucus Link.
*Penicillium glaucum Link.
*Penicillium bicolor Fries.
*Penicillium candidum Link.
**Penicillium humicola Oudem.
*Hormodendron cladosporioides Fres.
**Stysanus stemonites (P.) Corda.

Two or three forms are still unidentified. Those starred once, are species found also by Mr. Grossman in a clay soil in Ann Arbor. The ones starred twice, were also found by Oudemans and Koning in forest soil near Amsterdam. I shall not attempt in this paper to present drawings and descriptions of these forms. These will appear in the complete publication.

A few general comments only are offered at this time. By far the most abundant form found, was the *Fusarium*, which showed a characteristic pinkish white mycelium and sickle shaped spores, borne on short side branches. These simple fructifications were found to develop later into a *Cephalosporium* stage, which showed globular heads of spores, inclosed in greater or less quantities of slime. This transition was quite distinct, and seems to confirm entirely the idea of a *Cephalosporium* stage of *Fusarium*.

Moreover, this *Fusarium* is believed to be the cause of a fatal wilt disease, which was found affecting many garden flower plants, growing near the experimental plat. This belief is based on the following evidence: Stems of the wilted plants were sterilized on the outside by being placed for one or two minutes in a .1% solution of bichloride of mer-

cury. Then certain of these were placed in a damp chamber, where a *Fusarium,* having the specific characters of those from the experimental plat, was developed within a couple of days, and isolated in a pure culture. No other fungi appeared. Transverse sections of affected stems were now taken and submitted to microscopic examination, which showed a compact network of hyphae filling many of the vessels of the vascular bundles. It remains to demonstrate this cause of the disease, by making proper inoculations of healthy plants with suitable controls. I hope to take up this further work sometime in the near future.

The next most abundant fungus was a species of Mucor, indicated as, —*Mucor* (*species?*). It has characteristic sporangia, but it is remarkable and somewhat difficult to identify, on account of the wide variability of its sporangiophores. In some situations, these form sympodially in very characteristic manner, while in other cases, racemose clusters of the monopodial kind are predominant. It was certainly demonstrated that there was frequently a transition from the one type to the other. This came about by the elongation of certain racemose side branches, which as they elongated, began to branch sympodially. The spores were decidedly oval. This with the sympodial character of the sporangiophore, seems to identify the species as "*ambiguus.*" However, the racemose, monopodial development would, of course, throw it into an entirely different group. This wide variability might suggest the need of a new basis of classification for the whole group, or possibly, that this is a transitional form which shows extreme variations, allying it with both groups.

SUMMARY.

This investigation thus far, seems to justify the following generalization of results:

1. An abundant fungous flora exists habitually in the soil, and the forms which make up this flora, carry out at least a part of their work and respective life histories in this habitat.

2. This flora is to a conspicuous degree, constant in different soils, and also, rather uniformly distributed at all depths, at least as low as 14 centimeters. The species found belong mostly to the Hyphomycetes, or Imperfects; but include also a few of the Mucoraceae, among the Phycomycetes.

3. Tillage and manuring, so far as observations have been extended, seem to produce little change in the number and kind of species present. This statement is based on a study of samples taken from a manured plat, three months after the manure was applied, so that the fertilizer had become well decayed and mixed with the soil.

4. Many of these fungi show striking variability in their structural characters, when cultivated on media of constant composition.

5. One form which shows the structural characters of both *Fusarium* and *Cephalosporium*, is the probable cause of a destructive wilt disease which attacks several species of garden flowers, including *Aster, Sweet-pea, Zinnia,* and *Salvia splendens.*

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University of Michigan, April 20, 1911.

UNREPORTED MICHIGAN FUNGI FOR 1910, WITH OUTLINE KEYS OF THE COMMON GENERA OF BASIDIOMYCETES AND ASCOMYCETES.*

C. H. KAUFFMAN.

The field study of Michigan fungi during the past season was largely limited by the severe drought during July and August. Collections were made at Ann Arbor in the spring and during October and November. The month of September was spent at New Richmond, a village on the Kalamazoo River, south of Holland. Copious rains during this month made it possible to get quite a fair idea of the fall fungous flora of the lower Kalamazoo River, in a region once covered by magnificent white pine forests. Here one could pass readily from the sandy plains to clay ravines, or from the elm swamp to cedar and tamarack swamps, and these variations in soil and forest makes this region a veritable paradise for the mycologist. Hemlock and beech abound and the marks of a Northern flora are in evidence.

This paper is again composed of two parts: First, a list of hitherto unreported species along with some additional notes on species of Russulas; second, outline keys to the common genera of Basidiomycetes and Ascomycetes. These were prepared for use in my classes, and have been tested to that extent. There are no doubt various shortcomings, yet they seemed very useful, and it was suggested that I put them into some available form. The polyporaceae keys have been taken as far as the species with special regard for their usefulness in the field. It is hoped that they will be useful to those students who do not yet have access to the larger works.

I. UNREPORTED SPECIES.

ASCOMYCETES.

Helvellaceae

Gyromitra brunnea Underwood. On the ground, low woods of maple and oak. Washt. Co., April 28, fide C. H. K.

Gyromitra gigas (Kromb.) Cke. var. One specimen of a large Gyromitra was found on May 5, in low wet elm woods near Ann Arbor, which has some aberrant characters. The description follows: Hymenophore 20 cm. broad, 15 cm. high, coarsely and densely lobed in irregular pleats and folds, more or less attached to stem below, *rufous-cinnamon inclining to umber.* Stem 8 cm. long, 8 cm. broad, covered with a snow-white pruinosity, somewhat grooved to lacunose, solid, or slightly cavernous with small cavities. Asci about 400 micr. long, 18 micr. broad, 8-spored, uniseriate. Paraphysis septate, filled with brown granules, tapering

*Contribution No. 127 from the Botanical Department of the University of Michigan.

from apex, branched, slender, 6 micr. thick above. Spores 30-33x 13-16 micr., *elliptical*, not fusiform, hyaline, *rough-tuberculate*, ends warty. This seems to differ in essential points from G. esculenta, G. gigas and G. suspecta. The spores are rough, and contain a large central oil-globule and a minute globule at each end. The fresh specimen weighed two and two-fifths pounds.

Pezizaceae.

Plicaria fimeti (Fuckl.) Rehm. (syn. Humaria fimeti Fuckl.) On cow dung. Washt. Co., April 6, fide C. H. K.

Acetabula vulgaris Fuckl. On the ground, low grassy places. Washt. Co., June 1. Allegan Co., Sept., fide C. H. K.

Humaria humosa (Fr.) Cke. On mud and mosses. Washt. Co., June 6, fide C. H. K.

Humaria applanata (Hedw.) Rehm. (Syn. Peziza applanata.) On moist clay soil. Allegan Co., Sept. 24. fide C. H. K.

Neotiella polytrichi (Schum.) Mass. (Syn. Barlaea polytrichi Schum.) On moss, Polytrichum sp. Washt. Co., fide Durand.

Ascobolaceae.

Ascobolus glaber Fr. On cow dung, Steere's swamp. Washtenaw Co., fide C. H. K.

Helotiaceae.

Chlorosplenium chlora Schw. (Syn. Chlorosplenium Schweinitzii Fr.) Decaying wood. Washtenaw Co., Sept., fide C. H. K.

Coryne atrovirens (Pers.) Sacc. On decaying wood. Allegan Co., Sept. 25, fide C. H. K.

Phialea vulgaris (Pers.) Rehm. On fallen twigs of Salix amygdaloides. Washtenaw Co., Nov. 12, fide C. H. K.

Mollisiaceae.

Tapesia sanguinea (Pers.) Rehm. On decaying wood. Washtenaw Co., Nov. 12, fide C. H. K.

Eutuberaceae.

Tuber Borschii Vitt. On sandy hillsides of maple, oak, hemlock, bordering a cedar swamp. Allegan Co., Sept. 15. Fide C. H. K.; leg. Mrs. C. H. Kauffman.

Hypocreaceae.

Cordyceps superficialis Pk. (Not C. acicularis Rav. of the North American Flora.) Description as follows: Stromata gregarious, brownish-yellow to reddish-yellow, elongate, slender, often flexuous, furfuraceous, 3-5 cm. high, 1 mm. thick, the cylindrical stalks arising often from a net-work of strands, fertile heads hardly thicker than the stalk, except from the thickness due to the subsuperficial perithecia, acuminate and sterile at apex for 2-4 mm.; perithecia nearly superficial, loosely aggregate, oval, reddish-flesh-color, 65-70 micr. long; asci cylindrical, narrowed below, or slightly narrower at both ends, 150-175 micr. long, 5-6 micr. thick. Spores filiform, hyaline, at length many-celled, 1 micr. thick.

The sterile, acuminate-pointed apex, superficial, reddish, small perithecia, and gregarious, subcaespitose stromata, separate this from *C. acicularis* and *C. stylophora*. Growing on larvae, among rotting debris of woods. Near South Haven. July, fide C. H. K. leg. Mrs. C. H. Kauffman.

Hypocrea citrina (Pers.) Fr. Incrusting moss and decaying stump in patches 2-4 inches in diameter. Allegan Co., Sept. 1, fide C. H. K.

BASIDIOMYCETES.

Hypochnaceae.

Hypochnus Canadensis Burt sp. nov. ined. Whitmore Lake, Washtenaw Co., Nov. 2, fide Burt.

Dacryomycetaceae.

Dacryomyces deliquescens (Bull.) Dub. On limbs of trees and decaying wood. Frequent. Fide C. H. K.

Tremellaceae.

Tremella reticulata (Berk.) Farlow. On the ground, among grass in woods. Washt. Co., Nov. 12, fide C. H. K.

Clavariaceae.

Clavaria falcata Fr. Grassy places. Van Buren Co., July 5, fide C. H. K.

Clavaria exigua Pk. On the ground under Hemlock trees. Allegan Co., Sept. 18, fide C. H. K.

Thelephoraceae.

Coniophora puteana B. & C. On decayed flooring of an old house, city of Ann Arbor. Sept. 3, fide Burt.

Coniophora subochracea Pk. On decaying Fomes, on a Tamarack log. Horse-shoe lake, Washt. Co., Nov. 13, fide Burt.

Corticium Berkeleyi Cke. On rotten wood. Whitmore Lake, Washt. Co., Nov. 9, fide Burt.

Corticium bombycinum (Summerf.) Fr. On moss and bark of Populus tremuloides. Chelsea, Mich., Nov., fide Burt.

Corticium cremicolor B. & C. On dead limbs of domestic Cherry. Washt. Co., Nov., fide Burt.

Corticium polyparoideum B. & C. On rotten wood. Washtenaw Co., Nov., fide Burt.

Corticium vellerium Ell. & Craig. On Elm and Tamarack trunks. Horse-shoe Lake, Washt. Co., Nov. 13, fide Burt.

Hymenochaete cinnamomea Fr. On dead wood of Corylus. Washt. Co., Nov. 10, fide C. H. K.

Peniophora sera (Pers.) Burt. On very rotten wood. Washt. Co., Nov. 12, fide C. H. K.

Stereum fasciatum Schw. On oak limbs. Washt. Co., Oct. 19, fide Lloyd.

Stereum radiatum Pk. Horse-shoe Lake, Washt. Co. On Tamarack logs, Nov. 13, fide C. H. K.

Stereum rameale Schw. Washt. Co., fide Lloyd.

Polyporaceae.

Favolus striatus E. & E. On decaying limbs. Washt. Co., June 5, fide C. H. K.

Merulius subaurantiacus Pk. On bark of a Tamarack log. Horseshoe Lake, Washt. Co., Nov. 13, fide Burt.

Polyporus albellus Pk. On Elm log. Washt. Co., Nov. 10, fide Lloyd.

Polyporus lacteus Fr. On Oak limbs. Washt. Co., Nov. 12, fide C. H. K.

Poria pulchella Schw. Horse-shoe Lake, Washt. Co. On Oak rails, fide Lloyd.

Trametes protracta Fr. (Syn. T. vialis. Pk., T. trabea Bres.) On decaying Populus tremuloides. Chelsea, Nov. 10, fide Lloyd.

Hymenogastraceae.

Gautiera morchelliformis Vitt. Wooded hillsides, Cascade Glen, Ann Arbor. Oct., fide C. H. K.

Lycoperdaceae.

Geaster rufescens Fr. Washt. Co., fide C. H. K.

Agaricaceae.

Amanita russuloides Pk. Abundant on sandy ground covered by scrub Oak. Allegan Co., Sept., fide C. H. K.

Amanita spreta Pk. Sandy ground under trees. Allegan Co., Sept., fide C. H. K.

Bolbitius vitellinus Fr. On dung in elm swamp. Washt. Co., June, fide C. H. K.

Clitocybe monadelpha Morg. (Not C. tabescens of Bres.) Ground, Pine and Beech woods. Allegan Co., Sept. 24, fide C. H. K.

Clitocybe peltigerina Pk. On a lichen, Peltigera. Washt. Co., Apr. 5, fide C. H. K.

Clitocybe pinophila Pk. On a bed of White Pine needles. Allegan Co., Sept. 23, fide C. H. K.

Clitopilus subplanus Pk. On the ground, mixed woods. Allegan Co., Sept., fide C. H. K.

Collybia fusipes (Bull.) Fr. On the ground, frondose woods. Washt. Co., May 25, fide C. H. K.

Collybia succinea Fr. On the ground, hemlock and beech woods. Allegan Co., Sept. 22, fide C. H. K.

Coprinus ebulbosus Pk. On the ground among decaying logs. Washt. Co., June 1, fide C. H. K.

Cortinarius Catskillensis. Pk. Hillside, edge of Cedar swamp. Allegan Co., Sept., fide C. H. K.

Cortinarius jubarinus Fr. On very rotten conifer log Allegan Co., Sept. 6, fide C. H. K.

Cortinarius tortuosus Fr. On the ground, mixed hemlock ravines. Allegan Co., Sept., fide C. H. K.

Crepidotus dorsalis Pk. On rotten stump. Allegan Co., Sept. 9, fide C. H. K.

Crepidotus putrigenus B. & C. On decaying Sycamore stump. Van Buren Co., July 18, fide C. H. K.

Deconica atrorufa (Schaeff.) Fr. Ground in low woods. Washt. Co., June 5, fide C. H. K.

Entoloma dystale Pk. On the ground, in a ravine of Hemlock, etc. Allegan Co., Sept. 11, fide C. H. K.

Entoloma lividum (Bull.) Fr. On the ground, woods of White Pine and Beech. Allegan Co., Sept., fide C. H. K.

Entoloma rhodopolium Fr. Ground in mixed hemlock and maple woods. Allegan Co., Sept. 12, fide C. H. K.

Entoloma suave Pk. var. On sandy ground, edge of a marsh. Holland, Ottawa Co., Aug. 10.

Our specimens differ from Peck's description in the pileus which is hygrophanous and not umbilicate. Mr. Morris, who

first found it and from whose specimens it was described, writes me that it is likely that the plants were hygrophanous. Our specimens had non-angular spores like those of the type, scattered ventricose and obtuse cystidia about 60x20 microns, gills with a fimbriate edge and pileus somewhat pruinose. It may turn out, however, to be a distinct species. Unfortunately the specimens were lost.

Hebeloma magnimamma Pk. Ground in cedar swamp. Allegan Co., Sept. 12, fide C. H. K.

Hebeloma mesophaeum Fr. Ground under hemlock trees. Allegan Co., Sept. 18, fide C. H. K.

Hebeloma sarcophyllum Pk. Reported in 8th Report as *H. album Pk.*

Heliomyces nigripes (Schw). Morg. Ground in mixed woods of pine and beech. Allegan Co., Sept., fide C. H. K. (Syn. Marasmius nigripes).

Inocybe griseoscrabrosus Pk. On the ground, mixed woods. Allegan Co., Sept. 28, fide C. H. K.

Inocybe perbrevis (Weinn) Karst. On the ground, woods. Allegan Co., Aug. 28, fide C. H. K.

Inocybe proximella Karst. On the ground, woods. Van Buren Co., July 16, fide C. H. K.

Lactarius glyciosma Fr. On mossy log in swamp. Allegan Co., Sept. 23, fide C. H. K.

Lactarius paludinellus Pk. Wet ground, hemlock and maple woods. Allegan Co., Sept. 8, fide C. H. K.

Lactarius parvus Pk. Low, wet places, cedar and hemlock swamps. Allegan Co., Sept., fide C. H. K.

Lepiota adnatifolia Pk. On forest debris, mixed woods. Allegan Co., Sept., fide C. H. K.

Marasmius albipes Pk. Among fallen white pine needles. Allegan Co., Sept. 24, fide C. H. K.

Marasmius biformis Pk. Wet places, tamarack swamp. Allegan Co., Sept., fide C. H. K.

Marasmius delectans Morg. On the ground in clay ravines of hemlock and beech. Allegan Co., Sept. 18, fide C. H. K.

Marasmius felix Morg. Among fallen leaves. Washt. Co., Oct. 11, fide C. H. K.

Marasmius subnudus (Ell.) Pk. On the ground, mixed woods of pine and beech. Allegan Co., Sept. 23, fide C. H. K.

Mycena denticulata Pk. On rotten wood. Washt. Co., June 4, fide C. H. K.

Mycena dissiliens Fr. On decaying log in hemlock and beech woods. Allegan Co., Aug. 29, fide C. H. K.

Mycena polygramma var. albidus Fr. A large, well-marked form, if not a distinct species. On logs in frondose woods of Elm, Basswood, etc. June, fide C. H. K.

Mycena setosa (Sow.) Fr. On pine needles, etc. Allegan Co.. Sept. 24, fide C. H. K.

Mycena vitilis Fr. On the ground, cedar swamp. Allegan Co., Sept. 12, fide C. H. K.

Nolanea fuscogrisella Pk. On the ground in open copses. Oakland Co., Oct. 26, fide C. H. K.

Nolanea nodospora Atk. Low ground, mixed woods. Allegan Co., Sept., fide C. H. K.
Omphalia onisca. Fr. Ground of clay ravines under hemlock, etc. Allegan Co., Sept. 25, fide C. H. K.
Pholiota curvipoda A. & S. On elm log. Washt. Co., June 6, fide C. H. K.
Pleurotus candidissimus B. & C. On wood. Allegan Co., Sept. 10, fide C. H. K.
Psathyrella crenata Fr. On grassy ground. Allegan Co., Sept. 22, fide C. H. K.
Psilocybe murcida Fr. Low, wet places in woods, among grass, etc. Washt. and Allegan Co., June-Sept., fide C. H. K.
Stropharia epimyces (Pk.) Atk. Parasitic on Coprinus atramentarius and C. comatus. Port Huron, St. Clair Co, fide C. H. K.
Stropharia melasperma (Bull.) Fr. In pastured woods of white pine, beech, etc., on the ground. Allegan Co., Sept. 22, fide C. H. K.
Tricholoma panoeolum Fr. var. caespitosum Bres. On the ground in woods. Washt. Co., etc., fide Atk. A very confusing species, and easily taken for a Clitocybe; its spores are slightly flesh tinted.
Tubaria canescens Pk. Grassy places in woods. Allegan Co., Sept. 26, fide C. H. K.

ADDITIONAL NOTES ON THE GENUS RUSSULA.

Russula densifolia Secr.

A fine and typical specimen of this species was found in October at Ann Arbor, among grass in an oak woodlot. The flesh was whitish to grayish slowly changing to dull red when bruised, then becoming black. The gills were crowded even after the pileus was fully mature, relatively narrow. The pileus was up to 12 cm. broad, viscid, buff-colored, clouded with pale smoky brown when fresh. Taste tardily acrid, at length quite strong. Odor none. I am convinced that this species is quite distinct as Russulas go. Its taste separates it from *R. adusta*, its lack of odor from *R. compacta* and its gills and red stains from *R. nigricans*. The spores are spherical, tuberculate, 8-9 micr. diam., short apiculate, white in mass.

Russula brevipes Pk.

This seems to be merely an ecological variety of *R. delica*. Many specimens were found at New Richmond in a white pine and oak woodlot, pushing thru the hard, clay soil. It is smaller and the gills are close, but in every other respect it showed all the characters of *R. delica*. Conditions of weather and soil are no doubt responsible for this form. The typical *R. delica* delights to grow in sandy soil.

Russula decolorans Fr. Var. rubriceps Var. Nov.

The shape of the young and old pileus is well represented in Cooke's figure of *R. decolorans*, Plate 1079. The color of the pileus is, however, ruber-red (Sacc. colors) and persistent, changing only in age or on dry-

ing as a result of the cinerescent flesh. The pellicle is adnate, scarcely separable except on the margin, vanishing on the disk and sometimes ochraceus-spotted where the pellicle has disappeared. It is firm and the margin is not striate or very slightly so in age. These characters ally it to the Rigidae. It is slightly viscid. Flesh is firm, white, tinged ashy in age, becoming dark cinereous on the stem where bruised. The taste is mild and when fresh was taken for *R. lepida*. Spores creamy-white in mass. It is smaller, apparently, at least in our specimens, than the type. It is possible that it is a var. of *R. depallens Fr.*, but that species is not well understood even in Europe.

On the ground in beech and white pine woods. New Richmond, Allegan Co., Sept. Apparently rare.

The scarlet or vermillion pileus, cinerescent flesh, mild taste, creamy-white spores and firm consistancy are the distinguishing marks. The margin of the pileus is straight at first and the gills are broadest in front.

Russula atropurpurea Kromb. (non Pk.) sense of Maire.

Pileus 5-12 cm. broad, medium to large size, convex then plane, soon depressed, rather firm, viscid, pellicle adnate and scarcely separable on the margin only, scarlet to dark crimson when fresh and young, *becoming darker to purplish when mature or on drying, pruinose*, disk often darker sometimes livid olivaceus-purple, sometimes yellow-spotted, margin even or only slightly striatulate in age. Flesh dark red under the pellicle, white elsewhere, not changing to ashy. Gills *white,* dingy in age, rather narrow, close behind, subdistant in front, adnexed, few short. interspaces venose. Stem 4.7 cm. long, 1-3 cm. thick, subequal, medium stout, white with a dull lustre, pruinose, even, spongy-stuffed, apex floccose-punctuate. Spores white in mass, oval, 8-10 micr. diam., strongly echinulate, nucleate, apiculus long and stout. Taste *acrid*. Odor none.

Frequent in pine and beech woods. New Richmond, Allegan Co., Sept. Distinguished among the "ruber" group by the mode of color change while maturing, the white gills, spores and stem, and the acrid taste. It belongs to the Rigidae. In wet weather the cap is viscid, on drying its surface is distinctly pruinose. Except for the colors of the pileus it agrees with *R. ruber Fr.* in sense of Pk. It differs from *R. Queletii* which is a very variable species according to European mycologists, in its larger size and the lack of the deep violet color on pileus and stem. Maire refers the figures of Cooke's plates 1025 and 1087 of *R. rubra* to *R. atropurpurea Kromb.*, and these figures illustrate our plants fairly well except for the color changes.

Russula barlae. Quel.

Pileus 4-8 cm. broad, thin, medium size, ovate at first with straight margin, then convex-plane or depressed, very viscid, *fragile, pale rosy-flesh-color tinged with yellow*, sometimes peach-color, sometimes dull citron-yellow, varying in color from young to old, pellicle continuous and entirely separable, *margin becoming strongly tuberculate-striate.* Flesh thin, white, not changing color, soft. Gills *bright ochraceous-yellow* (flavus, Sacc.), white at first, rather narrow, broadest in front, narrow and adnexed behind, subdistant at maturity, dusted by the

spores. STEM 4-8 cm. long, 1-2 cm. thick, *subequal to ventricose,* soft and *fragile,* loosely stuffed then cavernous, (but not from grubs), white, rarely tinged with delicate pink, slightly wrinkled, subglabrous. SPORES subglobose, 7-9 micr. echinulate, nucleate, *bright ochre-yellow in mass.* TASTE *mild.* ODOR none.

Solitary or scattered. In mixed woods of hemlock and beech, among beds of white pine needles at New Richmond; among grass, etc., in oak woods at Ann Arbor, Sept.-Oct. Frequent.

This very fragile Russula is known from the other members of the "Fragiles" group, by its medium size, bright-yellow-ochraceus spores and gills, the hollow, often subventricose stem, the mild taste and the pinkish-yellow to peach-colored pileus. The stem is sometimes enlarged at apex, sometimes at base, always fragile. Very few of our Russulas have such bright-colored spores and gills. The color of the cap varies rather rarely to a deeper red on the one hand or to ochraceus-tan and straw-color on the other. The flesh does not change on bruising, and the odor is not noticeable even in age. It is very different from *R. integra Fr.* Quelet, its author, places it under the "Fragiles," while Massee refers it to *R. vesca* as a variety. The only excuse for this seems to be that Quelet's plant is said to have a "hard" stem. In this respect our plant differs but it is so close otherwise that it has been referred to it. It approaches *R. nitida* and is no doubt the plant usually referred to that species in this country. It differs from that species, however, in the lack of the nauseous, disagreeable odor, which Bresadola and others find to be constant, as well as its average larger size.

II. OUTLINE OF THE BASIDIOMYCETES AND ASCOMYCETES.

I. Mycelium non-septate. (i. e. without cross walls.) *Phycomycetes* (A.)
I. Mycelium septate. (i. e. composed of many cells.)............II.
II. Spores usually on a differentiated hymenium...............III.
II. Spores not on a differentiated hymenium, not in asci nor on basidia ....*Imperfect Fungi.* (Not included in keys.)
III. Spores borne on basidia, usually 4........*Basidiomycetes.* (B.)
III. Spores borne in asci, usually 8 ....*Ascomycetes.* (C.)

(B.) BASIDIOMYCETES.

(a) Basidia not formed on a hymenium, but on short hyphae arising from resting-spores. *Smuts and rusts.* (Not included in the keys.)
(a) Basidia formed on a hymenium..........................(b)
(b) Hymenium not on a special fruit-body, but developed directly from the hyphae which are hidden in the substratum. *Exobasidii.* (Not included in keys.)
(b) Hymenium developed on a special fruit-body...............(c)
(c) Hymenium exposed on the surface of the fruit-body. *Hymenomycetes.* (d)
(c) Hymenium concealed within the fruit-body till spores are mature. (See 10th Report Mich. Acad. of Sci. p. 63). *Gasteromycetes.*

(d) Basidia forked or divided by walls into 4 cells in various ways; plants usually gelatinous, horny when dry........*Tremellales.* (Not included in the keys.)

(d) Basidia clavate or subcylindrical, non-septate...*Agaricales.* (1.)

AGARICALES.

(1) Hymenophore* not differentiated, basidia scattered on a loose layer of hyphae. (Not included, seldom found)......*Hypochnaceae.*

(1) Hymenophore in form of gills, mostly fleshy plants. *Agaricaceae.* (e)

(1) Hymenophore in the form of erect branches or on an erect single club. ....*Clavariaceae.* (f)

(1) Hymenophore in form of wrinkles, warts, spines or tooth-like plates which form on one surface of the fruit-body; corky, woody, leathery or fleshy..........................*Hydnaceae.* (g)

(1) Hymenophore in the form of pores or reticulations on the lower side of the fruit body; woody, leathery, corky or fleshy. *Polyporaceae.* (h)

(1) Hymenophore even, its surface not differentiated like the preceding; mostly leathery, tough or woody, sometimes waxy-fleshy. *Thelephoraceae.* (k)

(*Agaricaceae.*)

(e) Spores mostly white .... (5)
(e) Spores ochre to cinnamon or rust-colored.................(21)
(e) Spores flesh-color to roseate or salmon-color...............(26)
(e) Spores purple-brown in mass.................................(30)
(e) Spores black in mass.......................................(33)

WHITE-SPORED AGARICS.

5. Gills of waxy consistency: *Hygrophorus.*
5. Gills not truly waxy:....................................(6)

6. Plants soft and fleshy, decaying:............................(7)
6. Plants toughish, corky, or woody; thin plants shrivel on drying, but revive when moistened ....(18)

7. Gills thick, narrow and forked dichotomously. *Cantherellus.*
7. Gills thinner ....(8)

8. Trama of pileus of both globular and filamentous cells........(9)
8. Trama filamentous thruout when young....................(10)

9. With milky juice: *Lactarius.*
9. Not with milky juice: *Russula.*

10. Stem eccentric, lateral or wanting: *Pleurotus.*
10. Stem central: ....(11)

* The term "hymenophore" is used to designate that portion of the fruit-body which bears the hymenium directly, e. g. gills, pores, spines, etc.

11. Gills free: ....(12)
11. Gills adnexed, adnate or decurrent..........................(13)

12. Volva and annulus present: *Amanita.*
12. Volva only present: *Amanitopsis.*
12. Annulus only present: *Lepiota.*

13. With annulus only: *Armillaria.*
13. Neither annulus nor volva present. ....(14)

14. Stem fleshy or fibrous, sometimes outer rind subcartilaginous: (15)
14. Stem cartilaginous, mostly thruout..........................(16)

15. Gills decurrent or broadly adnate, not sinuate at stem: *Clitocybe.*
15. Gills sinuate or emarginate at stem, often slightly so; mostly large plants; on ground: *Tricholoma.*

16. Gills decurrent, pileus umbilicate: *Omphalia.*
16. Gills not decurrent:..(17)

17. Plants small; pileus tending to remain unexpanded, bell-shaped: *Mycena.*
17. Plants medium to large; pileus usually expanded when mature; somewhat fleshy: *Collybia.*

18. Plants usually small, toughish, thin, not woody: *Marasmius.*
18. Plants usually larger, stem usually stout, central, eccentric, lateral or lacking ....(19)

19. Plant woody or corky: *Lenzites.*
19. Plant fleshy-leathery ....(20)

20. Edge of gills serrate: *Lentinus.*
20. Edge of gills entire: *Panus.*
20. Edge of gills split lengthwise, stem lateral or wanting. *Schizophyllum.*

OCHRE-SPORED AGARICS.

21. Veil cobweb-like (cortina); gills at length dark cinnamon or rusty from the spores: *Cortinarius.*
21. Veil not cobwebby; sometimes a slight cortina, but gills paler. (22)

22. Annulus present; veil which forms it is membranous, fibrous or cottony (not cobwebby). *Pholiota.*
22. Volva and annulus lacking:...................................(23)

23. Stem lateral or wanting: *Crepidotus.*
23. Stem central. ....(24)

24. Gills pale colored, sinuate at stem; stem fleshy or fibrous: *Hebeloma.*
24. Gills rusty or yellow, adnate or decurrent; stem fleshy: *Flammula.*
24. Stem cartilaginous: ....(25)

25. Pileus bell-shaped or conical; stem slender: *Galera.*
25. Pileus convex or plane; stem shorter and thicker: *Naucoria.*

PINK-SPORED AGARICS.

26. Stem lateral or lacking: *Claudopus.*
26. Stem central: ....(27)

27. Volva present only: *Volvaria.*
27. Volva and annulus lacking:..................................(28)

28. Gills free: *Pluteus.*
28. Gills adnexed, adnate or decurrent............................(29)

29. Gills sinuate; stem fleshy; plants rather large: *Entoloma.*
29. Gills decurrent; stem fleshy or fibrous: *Clitopilus.*
29. Stem cartilaginous; plants small, insignificant: *Eccilia, Leptonia* and *Nolanea.*

PURPLE-BROWN-SPORED AGARICS.

30. Annulus present; veil distinct:.............................(31)
30. Annulus and volva lacking:...................................(32)

31. Gills free: *Agaricus.*
31. Gills not free: *Stropharia.*

32. Veil present when young, seldom forming an annulus, sometimes remnants on margin of pileus, (appendiculate). *Hypholoma.*
32. Veil entirely lacking; fragile or delicate plants, unimportant: *Psathyra, Deconica, & Psilocybe.*

BLACK-SPORED AGARICS.

33. Gills deliquescing into a black fluid when mature: *Coprinus.*
33. Gills not deliquescing; volva and annulus lacking...........(34)

34. Pileus with striate or sulcate margin: *Psathyrella.*
34. Pileus not striate, rather firm: *Panoeolus.*

(*Clavariaceae*).

(f) Fruit-body fleshy, rather large, simple or branched, varying from half-inch to 6 inches or more high: *Clavaria.*
(f) Fruit-body not fleshy,—Clavaria-like but leathery and tomentose: *Lachnocladium.*
(f) Fruit-body slender, thread like, cartilaginous. *Pterula.*
(f) Fruit-body of the other genera are minute, mostly only several millimeters high.

(*Hydnaceae*).

(g) Hymenophore of gelatinous spines: *Tremellodon.*
(g) Hymenophore in form of folds or wrinkles. *Phlebia.*
(g) Hymenophore in form of minute warts, etc....................(1)
(g) Hymenophore with evident spines:...........................(2)
(g) Hymenophore with false gills or pores which become teeth in age: (4)

1. Warts rounded at apex: *Grandinia.*
1. Warts many-parted or ciliate at apex: *Odontia.*

2. Spines knob-like, thick, tufted or scattered, obtuse: *Radulum.*
2. Spines with acute tips.......................................(3)

3. Spores colorless: *Hydnum.*
3. Spores colored: *Phaeodon.*

4. Fruit-body leathery-tough: *Irpex.*
4. Fruit-body fleshy: *Sistotrema.*

(*Polyporaceae.*)

(h) Hymenophore reticulated or wrinkled. *Merulius.*
(h) Hymenophore of tubes, convoluted corriders, or variations of these ....(1)

1. Pileus fleshy or gelatinous, (decaying rapidly)................(2)
1. Pileus leathery, corky or woody, (a few may be tough-fleshy)..(6)

2. Stem lateral: *Fistulina.*
2. Stem central: ....(3)

3. Stem with an annulus: (usually incl. under *Boletus*)....*Boletopsis.*
3. Stem without volva or annulus..................................(4)

4. Pileus and stem squarrose-scaly: *Strobilomyces.*
4. Not squarrose-scaly: ....(5)

5. Layer of tubes separating readily from hymenophore: *Boletus.*
5. Layer of tubes not separating easily; tubes radiating from stem: *Boletinus.*

6. Hymenium gelatinous: *Gloeoporus.*
6. Hymenium not gelatinous ....(7)

7. Tubes in several layers; perennial. *Fomes.*
7. Tubes not stratified: annual...................................(8)

8. Tubes longer in the radial direction. *Favolus.*
8. Tubes rather regular:...(9)

9. Pileus thick, woody, corky or tough-fleshy, stalked or sessile. *Polyporus.*
9. Pileus thin, leathery or membranous:........................(10)
9. Pileus corky; tube-layer not distinct from trama of pileus....(11)

10. Pileus stalked or sessile shelving. *Polystictus.*
10. Pileus always entirely resupinate: *Poria.*

11. Tubes somewhat round. *Trametes.*
11. Tubes sinuous-labyrinthiform. *Daedalia.*

(*Thelephoraceae.*)

(k) Fruit-body infundibuliform and stalked, *Cantherellus*-like: hymenium ridged on the exterior. *Craterellus.*
(k) Fruit-body with even hymenium, but often showing the irregularities of the uneven substratum..............................(1)

1. Hymenium with projecting, bristle-like cystidia, showing under a pocket-lens: ....(2)
1. Hymenium without cystidia...................................(4)

2. Cystidia stellately branched: *Asterostroma.*
2. Cystidia simple: ....(3)

3. Cystidia hyaline; fruit-body of a one layered trama. *Peniophora.*
3. Cystidia colored; fruit body of more than one layer: *Hymenochaete.*

4. Pileus with substance in differentiated layers; usually effuso-reflexed, rarely stalked. *Stereum.*
4. Pileus of a homogeneous substance..........................(5)

5. Pileus resupinate, effused over the substratum in thin crusts:..(6)
5. Pileus stalked, or resupinate-reflexed, often much branched to form compound pilei. *Thelephora.*

6. Hymenium waxy or soft when fresh, cracked when old; spores colorless: *Corticium.*
6. Hymenium fleshy; spores colored. *Coniophora.*

POLYPORACEAE. (Field Keys to Species).

The important character comes first.

Names in parenthesis are those of the North American Flora, by A. W. Murril, where descriptions may be found.

Fomes.

1. Hymenophore flesh-color. ....(2)
1. Hymenophore not truly flesh-color. ....(3)

2. Flesh rose-colored; pileus usually small, flesh color when fresh; tubes 1-2 mm. long: *Fomes rosens Fr.*

2. Flesh flesh-color to cork-color; pileus 5 to 20 cm. wide; tubes 3-5 mm. long. *Fomes fraxinens Fr.*

3. Fruit-body mostly resupinate or effuso-reflexed...............(4)
3. Fruit-body usually shelving, dimidiate, ungulate or applanate. (5) (dimidiate = semicircular; ungulate = hoofed-shaped; applanate = flatly-extended).

4. Flesh thick, white or whitish; surface of pileus velvety, usually covered with a green growth of Moss, etc.; tubes 1-2 mm. long. *Fomes connatus Fr.* (Fomes populinus).
4. Flesh cinnamon-brown, thinner; fruit-body widely effused and resupinate (i. e. with hymenium uppermost). *Fomes conchatus Fr.* (Pyropolyporus conchatus).

5. Pileus small, less than 3 cm. wide; flesh whitish..............(6)
5. Pileus often considerably larger:...............................(7)

6. Pileus ungulate, zonate and concentrically sulcate in age. *Fomes ohiensis Berk.* (See also *Trametes*)
6. Pileus scutellate, (platter-shaped); surface even and black. *Fomes scutellatus Schw.*

7. Flesh white or whitish; (*Fomes pinicola* is brownish in age)..(8)
7. Flesh brown to ferruginous (rust-color)....................(11)

8. Surface of pileus chalk-white, or dingy white; on conifers, mostly Larix: *Fomes officinalis Fr.* cf. also *Fomes albogrisens PK.* (Fomes laricis).
8. Surface of pileus grayish-brown, brown or reddish:..........(9)

9. Growing on Ash; pileus ungulate, gray to blackish. *Fomes fraxinophilus PK.*
9. Growing mostly on conifers; at least not on Ash:............(10)

10. Pileus ungulate, resinous, sulcate, 6-10 cm. thick; margin often reddish to yellowish: *Fomes pinicola Fr.* (Fomes ungulatus).
10. Pileus irregularly extended, applanate, light-brown, .5-2 cm. thick; usually growing from roots or near the ground: *Fomes annosus Fr.*

11. Pileus applanate; surface white, gray or brown, concentrically sulcate; very common everywhere on dead timber: pores when fresh turn brown to black when bruised. *Fomes applanatus.* (Elfvingia megaloma).
11. Pileus ungulate: ....(12)

12. Flesh punky, homogeneous (i. e. not zonate); mostly on Birch and Beach: *Fomes fomentarius Fr.* (Elfvingia fomentarius).

12. Flesh woody, zonate; pileus brownish-black to ferruginous:..(13)

13. Surface of pores velvety—glistening; pileus deeply sulcate; tubes with abundant cystidia. *Fomes Everhartii E. & G.*
also Mucronoporus Everhartii.
(Pyropolyporus Everhartii).
13. Surface of pores dull; pileus radially cracked in age; spores colorless: *Fomes igniarious Fr.*
(Pyropolyporus igniarius).

Fomes lucidus F = Polyporus lucidus Fr.
Fomes carneus cke = Fomes roseus Fr.
Fomes nigricans Fr. = Fomes igniarius Fr. (?)
Fomes leucophaens Mont. = Fomes applanatus.
Fomes marginatus Fr. = Fomes pinicola Fr.
Fomes salicinus Fr. = Poria inermis Ell.
Fomes abietis Karst = Trametes Pini Fr.
Fomes ohiense Berk = Trametes ohienses.

Polyporus.

1. Pileus covered with a shining reddish-brown varnish; annual, sometimes perennial: ....(2)
1. Pileus with a different surface..............................(4)

2. Growing on Tsuga canadensis; fruit-body with a stem varnished like the cap: *Polyporus lucidus Fr.*
(Ganoderma tsugae).
2. Growing on broad-leaved trees; fruit-body sessile or short-stemmed. (3)

3. Fruit-body annual, mostly sessile, margin of pileus acute: *Polyporus sessile Murr.*
(Ganoderma sessile).
3. Fruit-body perennial; margin of pileus truncate: *Polyporus curtisii Berk.*
(Ganoderma curtisii).

4. Fruit-body stipitate: ....(5)
4. Fruit-body not stipitate, shelving or resupinate-reflexed......(27)

5. Flesh brown to yellow-ferruginous; on wood of conifers; or in oak woods: ....(6)
5. Flesh white: ....(7)

6. Pileus large, 15-20 cm. diam., surface hispid to strigose—tomentose, ferruginous, stained yellowish; flesh yellow-rusty, fragile when dry; stem short and thick; pores sulfur-greenish: *Polyporus Schweinitzii Fr.*
(Phoeolus sistotremoides)

6. Pileus less than 12 cm. broad, with a short, central, thick, tomentose stem; usually pileus is double, one beneath the other, rusty-yellow; pores at first white-covered, then grayish-brown:
Polyporus tomentosus Fr.
(Coltrichia tomentosa).
cf. Polyporus circinatus Fr.

7. Fruit-body grown together in the form of numerous pilei:......(8)
7. Fruit-body single or sub-caespitose ....(12)

8. Hymenophore yellow to greenish-yellow, decurrent; pilei becoming fragile, large, yellowish-green; stem 3-6 cm. long, thick:
Polyporus poripes Fr.
Grifola poripes).
cf. *Polyporus flavovirens* B. & Rav.
8. Hymenophore white; (tinged yellow in the first species following): ....(9)

9. On decayed trunks of apple trees; pilei tufted, each 10-15 cm. broad, white or tinged yellow; common stem short and very thick:*
Polyporus admirabilis PK.
9. On Larix and Cedar; pilei tough then hard, almost horny, even and glabrous; stems short, connate: *Polyporus osseus Fr.*
9. On the ground, or at base or around oak trees:...............(10)

10. Surface of pileus gray or grayish-brown to coffee-colored; pilei very numerous and small, 1-6 cm. broad each: ....(11)
10. Surface of pileus whitish to pale tan; pilei large, 5-15 cm. or more broad. Flesh milky in young plants; tubes large, 1 mm. diam.
Polyporus Berkeleyi Fr.
Grifola Berkeleyi).

11. Pilei lateral, spatulate or dimidiate: *Polyporus frondosus Fr.*
(Grifola frondosa).
11. Pilei central, umbilicate and circular: *Polyporus umbellatus Fr.*
(Grifola ramosissima).

12. Plants rather fleshy; growing on the ground ....(13)
12. Plants tough; on wood: ....(15)

13. Stem black and rooting; pileus subtomentose, smoky-brown:
Polyporus radicatus Schw.
(Scutiger radicatus).
13. Stem not black, nor rooting: ....(14)

14. Pileus blue when fresh; tubes blue when young:
Polyporus holocyaneus Atk. and Polyporus caeruleporus PK.
(Scutiger).
14. Pileus ashy-gray; tubes white-stuffed when young:
Polyporus griseus PK.
(Scutiger griseus).

15 Pileus stipitate, but stem usually aborted so as to be at times resupinate; flesh of two layers: *Polyporus distortus Schw.* (Abortiporus distortus).
15. Stem not aborted:................................(16)

16. Stem black, either at base or thruout, often lateral or eccentric:(17)
16. Stem whitish to brownish; pileus rarely more than 2-5 cm. broad:................................(20)

17. Pileus scaly, thickish, large, rather soft and putrescent; pores large, angular, shallow: *Polyporus squamosus Fr.* (Polyporus candicinus).
17. Pileus even, glabrous, firm becoming hard:..................(18)

18. Pileus large, 6-20 cm. broad................................(19)
18. Pileus smaller, pale leather-colored; stem central, abruptly black below: *Polyporus elegans Fr.*

19. Surface of pileus milk-white, center darker, tubes milk-white; stem smoky below; on roots from the ground: *Polyporus Underwoodii Murr.*
19. Surface of pileus chestnut colored to yellowish or blackish; stem entirely black: *Polyporus picipes Fr.*

20. Pileus zonate, mostly on the ground or on humus in woods:....(21)
20. Pileus not zonate:................................(22)

21. Pileus with lacerate margin, shining cinnamon: *Polyporus cinnamomeus S. F. Gray.* see: Polystictus cinnamomeus. (Coltrichia cinnamomeus).
21. Pileus with fimbriate or entire margin, rusty-brown: *Polyporus perennis Fr.* see: Polystictus perennis. (Coltrichia perennis).

22. Margin of the pileus strigose-hairy; mouths of tubes large, rhomboid: *Polyporus arcularius Fr.*
22. Margin of pileus not strigose:................................(23)

23. Surface of pileus fibrillose or villose-tomentose:...............(24)
23. Surface of pileus glabrous:................................(25)

24. Pileus drab-colored, tufted with fibrils, tubes milk-white, angular, decurrent: *Polyporus fagicola Murr.*
24. Pileus smoky to yellowish-brown, hispid-scaly; tubes whitish, round, adnate: *Polyporus brumalis Fr.* (Polyporus Polyporus).

25. Flesh yellow; surface of pileus bay-brown; tubes decurrent, mouths minute: *Polyporus phaeoxanthus B & M.*
25. Flesh white:................................(26)

26. Stem central, chestnut-colored; pileus white; tubes minute: *Polyporus albiceps PK.*
26. Stem lateral, white; pileus white; tubes angular, glistening: *Polyporus humilis PK.*

27. Flesh white or whitish:....................................(28)
27. Flesh brown, reddish or yellow ....(47)

28. Pores grayish-ashy, bluish or blackish in age................(29)
28. Pores not ashy in age: ....(32)

29. Pileus soft spongy when fresh, tomentose, friable when dry; spores blue to slate-color in mass: *Polyporus caesius Fr.* (Tyromyces caesius).

29. Pileus corky, glabrous or nearly so; spores white in mass:......(30)
30. Very fragrant when fresh; pileus 5-12 cm. broad, margin whitish; on Willow, etc.: *Polyporus suaveolens Fr.* (Trametes suaveolens).
30. Not fragrant; margin of pileus becoming black in age or when bruised; caespitose, fruit-body rather large:...............(31)

31. Pileus 5-20 mm. thick, smoky-colored, shelving, imbricate; tubes 2-3 mm. long; pores whitish at times: *Polyporus fumosus Fr.* (Bjerkandera fumosa).
31. Pileus thinner, 2-4 mm. thick, effuso-reflexed, often imbricate; tubes 1 mm. or less, long: *Polyporus adustus Fr.* (Bjerkandera adusta).

32. Surface of pileus distinctly hairy-tomentose and spongy, mostly white; rather large:..(33)
32. Surface of pileus glabrous or nearly so:.....................(36)

33. Flesh zonate, thin, only .5 to 1 cm. thick, rigid and brittle when dry; every part white or whitish: *Polyporus galactinus Berk.* (Spongipellis galactinus).
33. Flesh not zonate, pileus 2 to 5 cm. thick, not very brittle when dry: ....(34)

34. On trunks of conifers; parasitic; fruit-body white or tinged yellowish: *Polyporus borealis Fr.* (Spongipellis borealis).
34. Not known on conifers: ....(35)

35. Tubes large, 1 mm. in diam.; pileus large, 10-15 cm. wide, spongy when fresh, often ungulate, pale tan to cinnamon; on oak and maple: *Polyporus unicolor Schw.* (Spongipellis unicolor).
35. Tubes much smaller; pileus whitish to cream color or pale tan; flesh soft, spongy-fibrous. On beech: *Polyporus occidentalis Murr.* (Spongipellis occidentalis).

36. Pileus large, 8 cm. or more wide ....(37)
36. Pileus small, rarely exceeding 5 cm. wide:....................(40)

37. Flesh of two layers, soft and spongy above, firm and woody below; pileus whitish to pale tan, thick, convex to triangular; on elm, maple, etc.: *Polyporus delectans PK.* (Spongipellis delectans).
37. Flesh at first fibrous-fleshy, rigid and friable when dry, one-layered; pileus applanate or convex:................................(38)

38. Flesh zonate; pileus white, surface watersoaked, becoming discolored; margin soon blackish; odor strong; on oak: *Polyporus Spraguei Berk.* (Tyromyces Spraguei).
38. Flesh not zonate; pileus attached by narrow base:............(39)

39. Tubes 8-10 mm. long; pileus rugose, whitish or tinged yellowish; on Tilia: *Polyporus tiliophila Murr.* (Tyromyces tiliophila).
39. Tubes shorter, 3-6 mm.; pileus 10-15 cm. broad, white or yellowish, watery-spotted; on conifer trunks: *Polyporus guttulatus PK.* (Tyromyces guttulatus).

40. Surface of pileus cartilaginous, yellowish-white; flesh horny when dry, very thin; on maple, etc.: *Polyporus semisupinus B. & C.* (Tyromyces semisupinus).
40. Surface not cartilaginous: ....(41)

41. Pileus effuso-reflexed:.....................................(42)
41. Pileus dimidiate: ....(45)

42. Tubes large, irregular, 1-2 to a mm.; pileus white, sulate-zonate, slightly spongy-tomentose; on hemlock and pine: *Polyporus undosus PK.* (Tyromyces undosus).
42. Tubes much smaller, 3-6 to a mm., regular; pileus slightly villose or scabrous, laterally elongate: .... (43)

43. On coniferous wood:...(44)
43. On branches of broad-leaved trees; pileus white to tan; tubes short, very minute, often blue spotted: *Polyporus semipileatus PK.* (Tyromyces semipileatus).

44. Mouths of pores glistening; pileus subcorky, inseparable from substratum, milk-white, not zonate: *Polyporus anceps PK.* (Tyromyces anceps).
44. Mouths not glistening; pileus fleshy-tough, white to pale tan, often with reddish zones: *Polyporus Ellisianus Murr.* (Tyromyces Ellisianus).

45. Pileus zonate, whitish with brownish zones, 2-4 mm. thick, laterally much elongate, margin undulate and irregular; on Tsuga canadensis: *Polyporus crispellus PK.* (Tyromyces crispellus).

45. Pileus not zonate, much thicker; pores glistening:............(46)

46. Pileus milk-white, very soft and fleshy, becoming fragile and rigid when dry; tubes long, 5-10 mm.; on conifers and other wood: *Polyporus lacteus Fr.* (Tyromyces lacteus).

46. Pileus grayish-white to yellowish-white, watery with an acid odor; tubes short, 2-4 mm. long: *Polyporus chioneus Fr.* (Tyromyces chioneus).

47. Pores whitish, then black-spotted; pileus and flesh reddish-gray to clay color, dull red after wetting, with odor of seneca grass: *Polyporus fragrans PK.* (Bjerkandera puberula).

47. Pores and flesh whitish, yellow or orange; pileus velvety to finely tomentose: ....(48)

47. Pores and flesh light brown to dark brown:..................(50)

48. Pileus 2-3 cm. thick, orange colored, convex; flesh zonate, watery (fresh), rigid (dry); pores long, 5-10 mm. On oak, perhaps on other wood: *Polyporus Pilotae Schw.* (Aurantioporus Pilotae).

48. Pileus thinner, 1 cm. or less thick, applanate, imbricate, often of many pilei:...(49)

49. Very imbricate, sulfur-yellow, fading to white, large, 7-20 cm. wide. On trunks of broad-leaved trees; parasitic: *Polyporus sulphureus Fr.* (Laetiporus speciosus).

49. Orange-colored, much smaller, 5-8 cm. wide; flesh spongy (moist), friable (dry); on wood of conifers: *Polyporus fibrillosus PK.* (Psychoporellus fibrillosus).

50. Parasitic on living stems of the currant bush; pileus ferruginous to umber, 5-10 cm. wide, conchate, tough and corky: *Polyporus ribesius Pers.* (Pyropolyporus Ribes).

50. On wood of broad-leaved trees; pileus dimidiate, simple or somewhat imbricate: ....(51)

51. Flesh distinctly zonate:.................................(52)

51. Flesh indistinctly or not at all zonate ....(54)

52. Pores glistening; pileus medium size:......................(53)

52. Pores dull, whitish when young, then resinous, dark brown; pileus of immense size, a foot or more wide; on oak: *Polyporus dryadens Fr.* (Innotus dryadens).

53. Pileus large, 10-14 cm. wide, dark rusty-brown, with thick margin; flesh thick, shining; on oak: *Polyporus dryophilus Berk.* (Innotus dryophilus).
53. Pileus smaller, 5-10 cm. wide, surface rusty-yellowish, darker in age, imbricate:
form (A) applanate, thin margin:
form (B) subtriangular to effuso-reflexed, but thick: *Polyporus gilvus Fr.* (Hapalopilus gilvus).
53. Surface of pileus hirsute (stiff-hairy), to tomentose:...........(54)
53. Surface glabrous or nearly so:............................(55)

54. Pileus large and thick, 3-5 cm. thick, spongy-corky, subungulate, surface hispid, yellow-furruginous then dark; tubes about 1 cm. long. On living trunks: *Polyporus hispidus Fr.* (Innotus hirsutus).
54. Pileus thin, .5 to 1 cm. thick, spongy-fleshy, flabelliform (fan-shaped), surface tomentose, grayish to ferruginous; tubes 3-5 mm. long; on dead and living trunks: *Polyporus perplexus Pk.* (Innotus perplexus).

55. Pileus large, 10-15 cm. broad, surface concentrically sulcate, ferruginous; margin whitish, on white oak: *Polyporus lobatus Schw.* (Elfvingia lobata).
55. Pileus smaller, tawny, 3-9 cm. broad:........................(56)

56. Pileus corky, rigid, radiate-rugose, margin thin; tubes glistening: *Polyporus radiatus Fr.* (Innotus radiatus).
56. Pileus fleshy-pliant, not rugose, margin thick; tubes hardly glistening; on sticks and branches: *Polyporus rutilans Fr.* (Hapilopilus rutilans).

Polystictus.

1. Pileus with a distinct central stem; mostly on the ground:....(2)
1. Pileus without a distinct stem:............................(3)

2. Pileus with a lacerated margin, shining cinnamon: *Polystictus cinnamomeus S. F. Gray* (Coltrichia cinnamomea).
2. Pileus with even or slightly hairy margin, rusty-brown: *Polystictus perennis Fr.* (Coltrichia perennis).

3. Fruit-body at first cup-like and sterile, attached by a narrow sessile base, later developing the fertile pileus on one side, whitish, zonate, not effuso-reflexed: *Polystictus conchifer Schw.* (Poronidulus conchifer).
3. Fruit-body without a differentiated earlier cup:.............(4)

4. Fruit-body orange, dimidiate, rather soft, fibrous-tomentose: *Polystictus aurantiacus Pk.*
4. Fruit-body not orange .... (5)

5. Tubes soon breaking up into Irpex-like teeth: .... (6)
5. Tubes entire, unless very old: .... (9)

6. Tubes violet-reddish: .... (7)
6. Tubes white, or becoming discolored in age; on wood of broad-leaved trees: .... (8)

7. On conifers; pileus effuso-reflexed, grayish-white, villose, flexible to rigid: *Polystictus abietinus Dicks.* (Coriolus abietinus).
7. On broad-leaved trees; imbricate, thin and parchment like: *Polystictus pergamenus Fr.*

8. Pileus effuso-reflexed, laterally connate, white; tubes 3-5 mm. long, diameter rather large: *Polystictus biformis Klotsch.* (Coriolus biformis).
8. Pileus dimidiate to fan-shaped, whitish; tubes 1-3 mm. long, diameter smaller: *Polystictus prolificans Fr.* (Coriolus prolificans).
9. Surface of pileus conspicuously hairy, zoned; pileus 3-8 mm. thick, corky-leathery, very variable; very common: *Polystictus hirsutus Fr.* (Coriolus nigromarginatus).

9. Surface of pileus glabrous or minutely velvety to tomentose: .. (10)

10. Surface of pileus conspicuously zoned: .... (11)
10. Surface of pileus inconspicuously zoned: .... (14)

11. On trunks of Abies balsamea; pileus dimidiate, villose-tomentose, drab-colored with paler zones: *Polystictus balsameus Pk.* (Coriolus balsameus).
11. Not on conifers: .... (12)

12. Pileus white or dingy white, pubescent, rather thick, imbricate radially lined or furrowed; tubes white: *Polystictus pubescens Fr.* (Coriolus pubescens).
12. Pileus of varied colors in zones, not white: .... (13)

13. Pileus dimidiate, very imbricate, with glabrous shining zones of bright colors when young, becoming darker with age; tubes glistening; very common: *Polystictus versicolor Fr.* (Coriolus versicolor).
13. Pileus circular, spatulate, or fan-shaped, very thin, brownish-tan, with darker zones; margin often lobed: *Polystictus planus Pk.* (Coriolus planellus).

14. Pileus 3-6 cm. wide, white to pale tan, fan-shaped:............(15)
14. Pileus very small, 1-1½ cm. broad, yellowish-brown; mostly on Sassafras: *Polystictus hirsutulus Schw.* (Coriolus hirsutulus).

15. Pileus rigid, tough, thin, margin lobed, attached by a tubercle, surface scabrous, uneven: *Polystictus Lloydii Murr.* (Coriolus Lloydii).
15 Pileus rather flexible, entirely glabrous, margin lobed; tubes 2-3 mm. long: *Polystictus concentricus Murr.* (Coriolus concentricus).

Polystictus barbatulus=Polystictus sericeohirsutus (on red cedar).
Polystictus pseudopargamems=Polystictus prolificans.
Polystictus radiatus=Polyporus radiatus.
See also Polystictus velutinus Fr.

Trametes.

1. Pileus usually very large, 10-20 cm. wide, imbricate, dimidiate, smoky chocolate-brown, flesh and pores umber, with a resinous luster; common: *Trametes benzoina Fr.* (Ischoderma fuliginosum).
1. Pileus much smaller:....................................(2)

2. Uniform cinnabar-red throughout; pileus thick; common on dry wood: *Trametes cinnabarinus Fr.* (Pycnoporus cinnabarinus).
2. Not red: ....(3)

3. Tubes splitting Irpex-like in age; pileus thin, zonate, pale brown to blackish-brown, 2-8 cm., resupinate-reflexed; flesh bordered by black lines near the tubes: *Tremetes mollis Fr.* (Antrodia mollis).
3. Tubes not Irpex-like; pileus laterally connate:...............(4)

4. Flesh white or whitish, pileus 1-3½ cm. wide:................(5)
4. Flesh brown to ferruginous; tubes large, 1 mm. in diam.; pileus 5-12 cm. wide: ....(7)

5. Pileus effuso-reflexed:.................................. (6)
5. Pileus ungulate, light-brown, concentrically sulcate in age; tubes stratified, chalky-white: *Trametes ohiensis Berk.* *See: Fomes ohiensis Berk.*

6. Pileus whitish to pale wood-colored, often radiate-furrowed, often dimidiate; on dry fence rails and similar situations: *Trametes sepium Berk.* (Coriolellus sepium).

6. Pileus cinnamon-brown, etc., reflexed portion very narrow; surface uneven, tomentose to strigose-hairy: *Trametes serialis Fr.* (Coriolellus serialis).

7. On living conifers, parasitic; pileus 5-8 cm. thick, hard and woody, very rough and deeply sulcate, tawny-brown to blackish, perennial; tubes stratified, irregular like Daedalia: *Trametes Pini Fr.* (Porodaedalia Pini). Syn.=*Fomes abietes Karst.*

7. On poplar trunks, saprophytic; pileus 1-3 cm. thick, corky, sometimes sulcate, ferruginous, tubes long, regular: *Trametes stuppea Berk.* (Funalia stuppea).

Daedalia.

1. On oak timber, stumps and trunks. Pileus large and imbricate, thick: *Daedalia quercina L.*

1. On poplar, willow, etc., common; pileus applanate; pores labyrinthiform to almost regularly round: *Daedalia confragosa Bolt.* (Syn.=*Trametes rubescens*).

1. On logs, stumps, limbs of trees, etc., very common; pileus cinereus with unicolorous zones, rather thin and leathery: *Daedalia unicolor Fr.*

(*C.*) *Ascomycetes.*

A. Asci in a *Perithecium* (=a rounded, oval, pear-shaped or beaked fruit-body in which asci form, usually opening by pore at apex): (B) *Pyrenomycetes.*

A. Asci in a *Hysterothecium* (=fruit-body elongate, boat-shaped, star-shaped, etc., opening by slit). (I) *Hysteriales.* (I) (*Phacidiales.*

A. Asci in an *Apothecium* (=Fruit-body at last cup-shaped exposing the hymenium, or with the hymenium over outer surface of fruit-body): (K) *Discomycetes.*

A. Asci enclosed within a fruit-body, which breaks into pieces at maturity or loses its walls, to free the spores: (O) *Tuberales.*

A. Fruit-body lacking; hymenium forming directly on mycelium: (P) *Exoascales.*

B. Perithecia spherical, without true ostioles (a differentiated mouth or pore-, dark-colored or black at maturity): (E) *Perisporiales.*

B. Perithecia with differentiated ostiole:......................(C)

C. Perithecia soft, brightly colored or hyaline, never black or hard. (white, yellow, red or blue): (F) *Hypocreales.*

C. Perithecia hard, dark-colored or black:....................(D)

D. Walls of perithecium scarcely distinguishable from the stroma in which they are imbedded: (G) *Dothidiales.*

D. Perithecia clearly differentiated, hard or carbonaceous, with or without a stroma: (H) *Sphaeriales.*

(E) *Perisporiales.*

E. Perithecia closed, with appendages: (a) *Erysibaceae.*
E. Perithecia without appendages:
(Not included) (b) *Microthyriaceae.*
(c) *Perisporiaceae.*

(a) *Erysibaceae.*

1. Appendages needle-like, enlarged at base: *Phyllactinia.*
1. Appendages hooked or coiled at their apex: *Uncinula.*
1. Appendages dichotomous at the apex:........................(2)
1. Appendages variously shaped:................................(3)

2. Perithecia containing only one ascus: *Podosphaera.*
2. Perithecia containing several asci: *Microsphaera.*

3. Perithecia containing only one ascus: *Sphaerotheca.*
3. Perithecia containing several asci: *Erysibe.*

(F) *Hypocreales.*

Hypocreaceae.

1. Spores hyaline:..(2)
1. Spores brown or dark-colored..................................(7)

2. Spores elliptical, 2-celled:..................................(3)
2. Spores elliptical or elongated-fusiform; 3-many celled: *Calonectria.*
2. Spores needle or thread-shaped; perithecia on a stroma:........(5)

3. Perithecia on a loose mycelioid stroma; growing on old Agarics, etc.: *Hypomyces.*
3. Perithecia not on decaying fungi:..............................(4)

4. Perithecia imbedded in a cushion-shaped or effused stroma; the 2 cells falling apart at maturity: *Hypocrea.*
4. Perithecia on top of the stroma, or stroma lacking; spores often forming numerous conidia in the Ascus: *Nectria.*

5. Stroma erect, growing from dead insects or larvae or "Tubers" hidden in the ground or wood: *Cordyceps.*
5. Not on insects or "Tubers:"...................................(6)

6. Infecting grains of rye and other grasses, which it causes to enlarge and turn blackish (Sclerotia): *Claviceps.*
6. Forming thin stromata around plant stems: *Epichloe.*

7. Spores spherical; causing a dangerous wilt-disease of Cotton, Cowpea and Watermelon, by the mycelium filling vascular system: *Necosmospora.*
7. Spores muriform (i. e. divided like a brick wall): *Pleonectria.*

(G) *Dothidiales.*

Dothidiaceae.

1. Stroma large, brown then black, forming deformities on twigs of Plum and Cherry trees: *Plowrightia morbosa.*
1. Stroma small, linear or in patches, black, on leaves of grasses, etc.: ....(2)

2. Spores 1-celled, hyaline: *Phyllochora.*
2. Spores 2-celled, hyaline: *Dothidella.*
2. Spores 2-celled, dark-colored: *Dothidia.*

(H) *Sphaeriales.*

a. Growing on dung: (m) *Sordariaceae.*
a. Not on dung:..(b)

b. Perithecia on the surface of the substratum, with long hair-like ostioles; no stroma: (n) *Ceratostomataceae.*
b. Perithecia with short ostioles, or if long and slender then beneath the bark: ....(c)
c. No stoma present; perithecia free on the surface, or more or less sunken into the substratum:..(d)
c. Stoma present; perithecia either in groups in its surface, or deeply imbedded in the stroma; stroma may be on the surface or within the substratum:..(h)

d. Perithecia free, or only in the substratum at their base: (o) *Sphaeriaceae.*
d. Perithecia sunken in the substratum, only exposing the short ostioles: ....(e)

e. Asci usually thickened at the apex; breaking open by a pore; ostioles stout or elongated: (p) *Gnomoniaceae.*
e. Asci not thickened at apex, exuding from ostioles at maturity: ....(f)

f. Walls of perithecia carbonaceous or thick; spores large, in a gelatinous envelope: (q) *Massariaceae.*
f. Walls of perithecia thin, membranous-leathery:..(g)

g. Asci clinging together in bunches, without paraphyses: (r) *Mycosphaerellaceae.*
g. Asci separate; paraphyses present: (s) *Pleosporaceae.*
h. Stroma spread out, margin undefined; perithecia upon it in close, irregular clusters: (t) *Cucurbitaceae.*
h. Perithecia deeply imbedded in the stroma ....(k)
k. Stroma formed from the changed bark or wood of the substratum; sometimes hardly distinguishable from neighboring wood tissue, sometimes sharply marked by a black line; mostly covered over by the bark except at point where the ostioles of the perithecia break through to the surface: (u) (*Valsaceae.* (*Melanconidaceae.*

k. Stroma either initiated under the bark and later becoming superficial, or entirely developed as cushions or even erect bodies on the surface of the substratum:................................(2)

1. Spores hyaline or pale brownish; stroma pushing up through the bark: (x) *Diatrypaceae.*
1. Spores blackish-brown, stroma on the surface, or as erect, club-shaped, black, single or branched, Clavaria-like bodies: (y) *Xylariaceae.*

(m) *Sordariaceae.*

1. Spores 1-celled: *Sordaria.*
1. Spores 4-many-celled: *Sporormia.*

(n) *Ceratostomataceae.* (Saprophytes.)

1. Spores hyaline, 1-celled: *Ceratostomella.*
1. Spores brown, 1-celled: *Ceratostoma.*

(o) *Sphaeriaceae.* (Saprophytes & hemisaprophytes).

1. Perithecia hairy or spiny: ....(2)
1. Perithecia smooth: ....(4)

2. Perithecia walls thin, membranous or leathery; spores several-celled, hyaline, fusiform: *Acanthostigma.* (*A. parasitica,* on Silver Fir).
2. Perithecia walls thick, carbonaceous or woody, friable:........(3)

3. Spores several-celled, fusiform, hyaline or brown: *Herpotricha.* (*H. nigra,* on larch, spruce, etc.).
3. Spores several-celled, cylindrical-curved, hyaline or brown: *Lasiosphaeria.*
3. Spores 1-celled, dark-colored: *Rosellinia (in part).*

4. Spores hyaline, 2-many-celled; perithecia warty on surface: *Bertia.*
4. Spores dark-colored, 1-celled: *Rosellinia.* (*R. necatrix,* on roots of trees, etc.) *R. aquila,* on Mulberry roots. (*R. Quercina,* on roots of Oak seedlings, etc.)

(p) *Gnomoniaceae.*

(Saprophytes or Hemisaprophytes) (Spores hyaline).

1. Spores 1-celled:...(2)
1. Spores elongated, 2-4-celled: *Gnomonia.* (*G. padicola* on cherry tree). (*G. leptostyle* on Walnut leaves).

2. Ascus 8-spored: .... (3)
2. Ascus many-spored: *Ditopella.*
(*D. fusispora* on Alder.)

3. Spores elliptical; on leaves and stems of herbs; ostiole rather long: *Gnomoniella.*
3. Spores sausage-shaped; on fruit and branches of the apple tree; the imperfect stage="Gloeosporium fructigenum:" *Glomerella.*
(*G. rufomaculans*).

(q) *Massariaceae.* (Saprophytes).

1. Spores more than 2-celled, brown, elliptical to fusiform; on branches of trees: *Massaria.*

(r) *Mycosphaerellaceae.* (Saprophytes and Hemisaprophytes).

1. Spores regularly 2-celled:.................................. (2)
1. Spores 1-celled, when old divided into 2 very unequal parts: *Guignardia.*
(*G. Bidwellii,* parasit. on Grapes).
(*G. Vacinii,* on Huckleberry).

2. Parasitic on leaves of living plants: *Stigmatea.*
2. Saprophytic on leaves, branches, wood, fruit, ferns, etc., perithecia minute; a large genus of about 500 species: *Mycosphaerella.*
(Syn=Sphaerella).
(*M. ulmi* on elm leaves).

(s) *Pleosporaceae.* (Saprophytes and Hemisaprophytes).

1. Spores 1-celled, hyaline or brownish: *Physalospora.*
1. Spores 2-celled: .... (2)
1. Spores more than 2-cells: .... (4)

2. Ostioles or perithecial wall with hairs or bristles; spores hyaline or brownish: *Venturia.*
(*V. Pomi*=Apple scab.
(*V. Pyrini*=Pear scab.
2. Perithecia not hairy:.......................................(3)

3. Spores hyaline: *Didymella.*
(*D. citri,* on Orange trees).
3. Spores brown: *Didymosphaeria.*

4. Spores with septa in one plane only: .... (5)
4. Spores muriform, i. e. with septa in several planes.............. (7)

5. Spores fusiform or elongated: .... (6)
5. Spores long thread-like, often breaking up into its component 3 cells: *Ophiobolus.*
(*O. graminis* on wheat).

6. Spores hyaline: *Metasphaeria.*
6. Spores yellow to brown: *Leptosphaeria.*

7. Perithecia hairy: *Pyrenophora.*
7. Perithecia smooth: *Pleospora.*
(P. gummipara, cause of formation of Gum-Arabic on Acacia).

(t) *Cucurbitaceae.*

1. Spores muriform, brown, several-celled: *Cucurbitaria.*
(*C. pithyophilia* on Abies pectinata).

(u) (*Valsaceae.*) (*Melanconidaceae.*)

1. Spores brown, 1-celled: *Anthostoma.*
1. Spores hyaline, 1-celled: ....(2)
1. Spores more than 1-celled:..................................(3)

2. Conidia layer formed in the upper layer of stroma, accompanying the perithecia: *Cryptospora.*
2. Conidia in pycnidia, or absent; on twigs and branches; common: *Valsa.*

3. Spores 2-celled, rarely 4-celled, hyaline........................(4)
3. Spores many-celled, brown: *Pseudovalsa.*

4. Conidia "spores" dark-brown: *Melanconis.*
4. Conidia hyaline or absent: *Diaporthe.*
(*D. parasitica* on Chestnut trees).

(x) *Diatrypeaceae.*

1. Stroma only with pycnidia; spores 1-celled, hyaline: *Calosphaeria.*
1. Stroma well-developed, finally on the surface of substratum....(2)

2. Asci 8-spored; spores cylindrical, curved, hyaline or pale-brown, 1-celled: *Diatrype.*
2. Asci many-spored; spores cylindrical, curved, brownish, 1-celled: *Diatrypella.*

(y) *Xylariaceae.*

1. Stroma crust-like, plate-like, spherical or hemispherical, etc., attached by entire lower surface; spores 1-celled:............(2)
1. Stroma erect, clavate, cylindrical or capitate, simple or branched; perithecia lacking toward base: *Xylaria.*

2. Stroma crust-like, effused or as scattered areas over the blackened substratum: *Nummularia.*
(*N. discreta* on Apple trees).
(*N. Bulliardi* on Beech trees).
2. Stromata in plates, cushions or globular patches:...............(3)

3. Stroma concentrically stratose: *Daldinia.*
3. Stroma not stratose: ....(4)

4. Stroma woody or carbonaceous, reddish, brown or black: *Hypoxylon.*
4. Stroma at first fleshy, then carbonaceous: *Ustulina.*

(1) (Hysteriales.) (Phacidiales.)

1. Fruit-bodies elongated or boat-shaped:........................(2)
1. Fruit-bodies angular, roundish or star-shaped:..............(6)

2. Hysterothecia imbedded in the substratum with which they are grown together:...(3)
2. Hysterothecia breaking through the surface of the substratum.(4)
2. Hysterothecia all upon the surface of the substratum, linear..(5)

3. Spores fusiform, 4-celled: *Gloniella.*
3. Spores filiform, 1-celled: *Lophiodermium.*
(*L. pinastri* on conifer-needles).

4. Spores elliptical, 1-many-celled, hyaline; on oak and beech branches: *Dichaena.*

5. Spores with 4-8 cells in a row, at length brown, elliptical: *Hysterium.*
5. Spores with 2-4 cells in a row, hyaline: *Glonium.*
5. Spores muriform, many-celled, hyaline to brown: *Hysterographium.*

6. Hysterothecium brown or black:...........................(7)
6. Hysterotherium not blackish; hymenium exposed by the folding-back of the covering layers:..............................(10)

7. Hysterothecium at first immersed, later breaking forth from substratum: ....(8)
7. Hysterthecium imbedded in the substratum, which is torn and folded back:...(9)

8. Spores muriform; on wood, minute: *Tryblidium.*
8. Spores needle-shaped, 2-8 celled, hyaline, on branches, stems, etc.: *Scleroderris.*

9. Without a stroma; spores 1-celled, hyaline, oval or fusiform; mostly on leaves: *Phacidium.*

9. Fruit-bodies in a stroma, which forms black patches on leaves; spores needle-shaped, 1-celled, hyaline: *Rhytisma.* (*R. acerinum* on maple leaves).
10. Spores elliptical, hyaline, 1-celled: Paraphyses much branched above; hymenium thin-margined. *Propolis.*
10. Spores filamentous, many-celled; paraphyses slightly branched; hymenium thick-margined: *Stictis.*

(K) *Discomycetes.*=L.

L. Hymenium on a differentiated upper part of fruit-body, which is stalked and fleshy, waxy or gelatinous (M) *Helvellales.*
L. Hymenium concave, even or convex, forming the upper surface of a usually cup- or urn-shaped fruit-body which is sessile or stalked. (N) *Pezizales.*

(M) *Helvellales.*

a. Fruit-body capitate; the cap spherical, elongated, etc., even, folded or ribbed, *fleshy*: (g) *Helvellaceae.*
a. Fruit-body clavate, fleshy or gelatinous; asci opening at apex by a pore. (h) *Geoglossaceae.*

(N) *Pezizales.*

b. Cups or disks of small size, growing on dung; sometimes on other substrata: (i) *Ascobolaceae.*
b. Not on dung; usually on earth, or on wood..................(c)

c. Cups fleshy or waxy, rarely gelatinous; ends of paraphyses free..(d)
c. Cups leathery or cartilaginous; ends of paraphyses united to form a thick layer over asci (=Epithecium).....................(f)

d. Cups generally large (1-5 cm.), fleshy structure of fruit-body of similar, parenchyma-like cells: (k) *Pezizaceae.*
d. Cups generally small or minute, waxy; structure of fruit-body of long, slender hyphae, outer layer often differentiated.........(e)

e. Hyphae of fruit-body all hyaline: Cups mostly minutely stalked; on wood and herbs: (l) *Helotiaceae.*
e. Outer hyphae of thick-walled brown cells; cups sessule; growing on herbs: (m) *Mollisiaceae.*

f. Cup free from the first upon the substratum, never enclosed in a membrane. (n) *Patellariaceae.*
f. Cup at first imbedded in the substratum, then breaking thru epidermis, often at first enclosed in evanescent membrane: (o) *Cenangiaceae.*

(g) *Helvellaceae.*

1. Cap continuous with stem; both hollow within:...............(2)
1. Cap loose around the stem, of variable shapes.................(3)

2. Large; cap 2-5 in. across with labyrinthiform folds, forming hymenial surface: *Gyromitra.*
2. Smaller; folds up and down and crosswise, forming irregular rows of pits. *Morchella.*

3. Cap composed of flaps hanging about the stem: *Helvella.*
3. Cap bell-shaped. *Verpa.*

(h) *Geoglossaceae.*

1. Apothecia with differentiated cap: (2)
1. Apothecia clavate, compressed: (3)

2. Gelatinous, green or yellowish; spores ellipt.—fusiform: *Leotia.*
2. Fleshy-leathery; spores filiform; cap yellowish to brownish: *Cudonia.*

3. Plants bright-colored: ....(4)
3. Plants black or blackish; spores 4-many-celled, brown or blackish: (6)

4. Apothecia spatulate to fan-shaped: *Spathularia.*
4. Apothecia clavate: ....(5)

5. Spores 1-celled: *Mitrula.*
5. Spores 4-many-celled. *Microglossum.*

6. Gelatinous: *Gloeoglossum.*
6. Not Gelatinous, without spines: *Geoglossum.*
6. Hymenium beset with spines: *Trichoglossum.*

(i) *Ascobolaceae.*

1. Spores hyaline. ....(2)
1. Spores at length violet or brown:.........................(3)

2. Apothecia hairy: *Lasiobolus.*
2. Apothecia smooth: *Ascophanous.*

3. Spores in a gelatinous envelope: *Saccobolus.*
3. Spores not in such envelope. *Ascobolus.*

(k) *Pezizaceae.*

1. Cup externally hairy: *Lachnea.*
1. Cup smooth on outside:....................................(2)

2. Cup split down one side, ear-shaped: *Otidea.*
2. Cup not split:..(3)

3. Juice of fresh apothecia milky: *Galactinia.*
3. Juice not milky:..(4)

4. Asci stain blue with iodine: *Plicaria.*
4. Asci not blue with iodine:.................................(5)

5. Spores with reticulate wall: *Aleuria.*
5. Spores not reticulate:.....................................(6)

6. Cup sessile; small: *Humaria.*
6. Cup more or less stalked:..................................(7)

7. Cup flattened out: *Discina.*
7. Cup goblet or beaker shaped: *Geopyxis.*
7. Cup on a long rough stem: *Macrapodia.*

(l) *Helotiaceae.*

1. Cup externally hairy:......................................(2)
1. Cup not hairy:...(4)

2. Cup large 1-5 cm., usually bright-red; in the spring. *Sarcoscypha.*
2. Cups minute; spores elliptical:............................(3)

3. Cups delicate, stalked: *Dasyscypha.*
3. Cups thick, sessile: *Lachnella.*

4. Substratum (i. e. wood) colored green by the fungous: *Chlorosplenium.*
4. Substratum not colored green:..............................(5)

5. Cups dark brown arising from "Sclerotia"; parasitic on plums, etc. *Sclerotinia.*
5. No "Sclerotia": ....(6)

6. Cup cartilaginous or gelatinous; spores many-celled: *Coryne.*
6 Cup waxy or tough:..(7)

7. Spores hyaline, 1-celled: *Hymenoscypha.*
7. Spores hyaline, 2-4 celled: *Helotium.*

(m) *Mollisiaceae.*

1. Cups gelatinous-horny; spores 1-celled: *Orbilia.*
1. Cups fleshy-waxy: ....(2)

2. Cups on a mycelioid subiculum: *Tapesia.*
2. Cups without subiculum:....................................(3)

3. Cups from the first upon the substratum: spores 1-celled hyaline, longish: *Mollisia.*
3. Cups at first immersed in the substratum; spores 1-celled:......(4)

4. Cups bright-colored: *Pseudopeziza.*
4. Cups dark, margin fringed: *Pyrenopeziza.*

(n) *Patellariaceae.*

1. Cup free, sessile, round; spores 2-celled, becoming brown: *Karschia.*

(o) *Cenangiaceae.*

1. Fresh cups leathery, horny or waxy:..........................(2)
1. Fresh cups gelatinous: *Bulgaria.*

2. Stroma present; spores many, conidia-like, germinating in ascus: *Tympanis.*
2. Stroma not present; spores one-celled, hyaline: *Cenangium.*
2. Cups large, blackish-brown, caespitose, stalked, urn-shaped, first closed; on buried sticks; spring. *Urnula.* (*Urnula Craterium*).

(o) *Tuberales.*

Plectascales.

1. Fruit-bodies subterranean. ....(2)
1. Fruit-bodies not subterranean:..............................(3)

2. Fruit-body with passages (Veins) branching thruout it, and opening to the exterior; the passages are lined with the hymenium. *Tuber.*
2. Fruit-body with a sharply differentiated thick peridium; hymenium irregularly distributed in masses, separated by sterile veins. *Elaphomyces.*

3. On old bones, hoofs, horns, hair, wool, etc., of animals; fruit-body usually stalked, capitate: *Onygena.*
3. Not on bones, etc.; fruit-body not stalked.....................(4)

4. Fruit-body usually in the interior of decaying vegetables, bread, etc., found with difficulty. The "imperfect stage" everywhere present as a "mould." *Asperigillus.* *Penicillium.*

(P) *Exoascales.*

Exoascaceae.

(Causing deformities on shrubs and trees.)

1. On leaves of Peach trees: (Peach-leaf Curl. *Exoascus deformans.*

2. On fruit of Plum and Wild Cherry: (Plum Pockets.) *Exoaseus pruni.*

3. On Cherry-trees: (Witches' brooms.) *Exoascus cerasi.*

4. On birch: (Witches' brooms.) *Exoascus turgidus.*

5. On alder-catkins: *Exoascus alni-incanae.*

6. On carpinus: (Witches' brooms.) *Exoascus carpini.*

7. On poplar-catkins: *Taphria aurea.*

April 20, 1911, Univ. of Mich.

MEASURING THE TRANSPIRATION OF EMERSED WATER PLANTS.

CHAS. H. OTIS.

The evaporation taking place from free water surfaces has been the subject of much experimentation during the past century and the laws governing this phenomenon have been quite definitely stated. But, although the matter is of great economic importance in regions of small rainfall and scant water supply, no one has yet determined what is the effect of emersed water plants on the evaporation from a water surface. During the summer of 1910 the writer carried on some experiments at Portage Lake (Washtenaw Co., Mich.) to determine what relations, if any, exist between the evaporation from a free water surface and the evaporation from a water surface occupied by certain plants growing in the water, but extending above the surface to a greater or less extent.

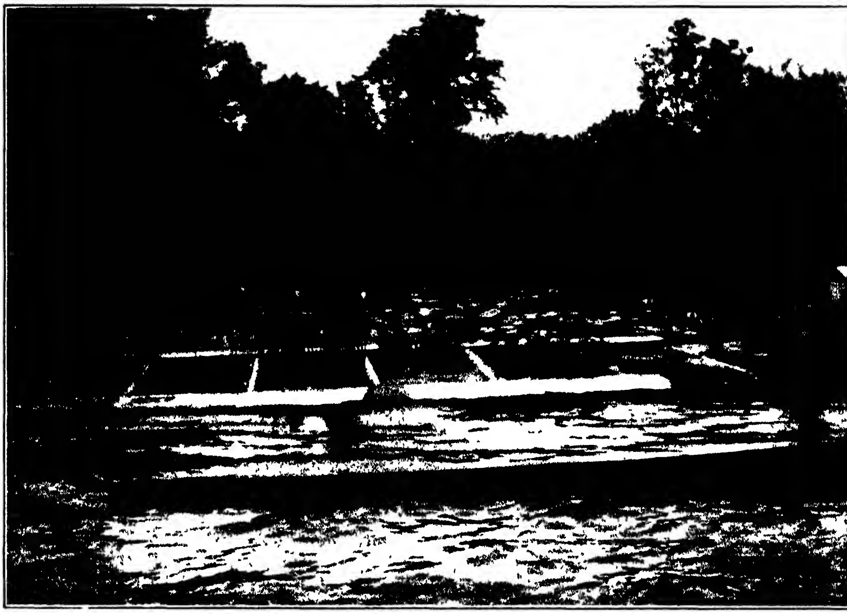
The apparatus used consisted essentially in a battery of nine large metal tanks supported in the water by two pontoons, each of these tanks being provided with a device for measuring the evaporation from the tank. A recording thermometer was maintained within a few feet of the battery, while a barometer, a psychrometer, thermometers for taking water temperature, and graduates for measuring the amount of water evaporated were employed.

The tanks were constructed especially for this work and were 30 inches in diameter by 32 inches in depth, inside measurements (Fig. 1). The cylinder and bottom were of heavy galvanized iron riveted and soldered. A heavy iron band encircled the rim, serving the double purpose of preserving the circular shape of the rim and of a support for the tanks. Lighter iron bands were placed at intervals along the height of the tank, to which were riveted internal iron braces, one of which may be seen at *a*, Fig. 1. The bottom of the tank was raised 4 inches from the edge, allowing two by fours to be fitted and spiked to the sides as a support for the bottom (Fig. 2). Holes were drilled in the uppermost band, allowing the tank to be supported by spikes driven into the cross pieces of the pontoons. The object was to obtain a tank so solid that it would not become deformed by the tilting caused by wave action, since any deformation of the tank while in position would cause a corresponding change in its volume.

The success of this apparatus was due in large part to a unique measuring device which was an integral part of the tank. A hollow brass tube extended through the center of the tank. The lower end of this tube was screwed into a socket which was riveted and soldered to the bottom of the tank in a central position, while its upper end terminated in a heavy brass socket into which fitted a solid brass rod which was held in place by a set screw in the side of the socket. This rod was pointed at its upper end, and, being turned up in a lathe,

Fig. 1

Fig. 2.



A Garden in the Lake

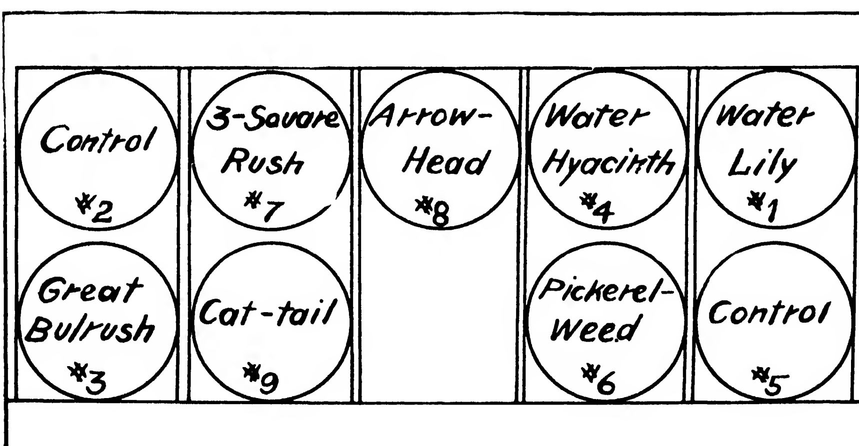


Diagram Showing Arrangement of Tanks

any point was uniform (as to the angle of the point) with any other point. The points were finished on an oil-stone, until a microscopical test showed them to be all of the same degree of sharpness. The angle of the cone was 45°, which was found to give the best results. Screwed into the sides of the socket at angles of 120° with each other were three iron radius rods terminating in the heavy iron band at the rim. By means of lock nuts and gaskets on either side of the tank these rods could be shifted, allowing the point to be centered with ease and accuracy. This was essential, for, with the point located centrally, it was possible, at least theoretically, to make correct readings whether the tank was vertical or tilted slightly.

Utilizing as it does the principles of the well-known Hooke gauge quite remarkable results were realized with this apparatus. Suppose that water is poured into a tank until it reaches the extremity of the point. By placing the eye close to the level of the water a position is found where the entire surface of the water appears like a bright mirror. If, now, a small quantity of water is removed, there appears in the center of the mirrored surface a minute black spot, which, though small, is readily distinguishable. Upon removing a little more water this dark spot rapidly enlarges, spreading out in a circle around the exposed point. Upon slowly replacing the water which was removed the dark circle diminishes in size, and at length a point is reached where it disappears entirely. If the finger is touched lightly to the water so that a tiny wave is sent across the surface, the spot bobs into view momentarily, showing that the point is just beneath the surface. Experience showed that this phenomenon was most readily observed when the sun was low and the light was less intense than at midday, that is, near sunrise and sunset. At noon the sun on a clear day is so intense that the eye is flooded with light and the dark spot is not readily seen. Again, at daybreak and sunset the air is almost calm, thus facilitating the operation of measuring and rendering the measurement more exact. Repeated observations under all conditions showed that on the average a change in the height caused by the adding or subtracting of 25 c.c. of water could be distinguished. Since the area of water surface in the tank approximated 4,575 sq. cm., this volume amounts to a theoretical difference in height of 1-20th of a millimeter.

The pontoons which supported the tanks in the water consisted of two boxes 14 feet long, 12 inches wide and 14 inches deep, constructed of rough hemlock lumber and covered with a good grade of asphalt roofing felt. The top was left loose so that any water which might get into the boxes might be bailed out and rocks might be put in to sink the tanks to the required depth. It was found to be an advantage to have these boxes made extra large in order that the necessary work of filling the tanks with soil and plants might be done from the pontoons, rather than from a boat. Cross members held the pontoons rigidly in place and the tanks were spiked to these. Poultry netting of 2 inch mesh was placed around the finished raft to a height of a foot, and also in the spaces not filled by the tanks. The purpose of the netting was to keep out the turtles which sunned themselves by the score on the pontoons. The station was sheltered from the prevailing westerly winds by the close proximity of a narrow neck of land which shut off the high waves. There was no natural protection on the south and east,

hence a break water was constructed far enough from the pontoons to allow a boat to pass between. The other two sides were closed in by a log boom, whose purpose was to keep inquisitive visitors at a proper distance.

Native plants for the most part were placed in the tanks, the water depth being regulated to suit the natural conditions of the various species used. Reference to the accompanying diagram will indicate the position of the various plant groups. Two tanks, as indicated, contained neither soil nor plants and were used to obtain the figures for the evaporation from the free water surface. The points were so placed that the surface of the water in the tanks was 1¾ths inches from the rim. Every leaf outline was traced on paper and every leaf stalk was measured at the beginning of the experiment, after which the pontoons were filled with rocks to bring the rims of the tanks to within 2 inches of the surface of the lake. As leaves died from time to time during the progress of the experiment, a record was made of the area of the leaf and time of its removal. At the close of the experiment the leaves and stems were again measured so that a curve of growth may be made for the period of time consumed, from which the area of surface exposed to the air at any time and for any species may be taken.

Measurements of the evaporation were begun August 8th and were continued with some interruptions until August 30th. Readings were made twice daily when weather conditions permitted, once in the early morning and again in late afternoon. A record was each time made of the volume of water added to bring the water level to the normal point. At the same time the temperature of the water within the tank was taken, both at the surface and just above the soil. The temperature of the water of the lake at the station was likewise ascertained both at the surface and at a depth of 30 inches. A whirling psychrometer was also used to ascertain the wet and dry bulb temperatures, from which the relative humidity has been derived.

Some of the data acquired at this station have been worked up. For the sake of ready reference and comparison these figures have been plotted graphically, charts I-VII. Chart I shows the evaporation which took place from the two control tanks, the average being represented by the heavy line. (Fractions of centimeters have been dropped to facilitate the plotting of the lines.) It will be noticed that the rate of evaporation from the free water surface was greater during the day than at night. A glimpse at charts II-VII shows this to a more marked extent. Allowing for any considerable error which might occur, these charts show conclusively that unsubmerged water plants transpire large quantities of water, and that this takes place principally during the daytime. The one exception in the plants used is the Water Lily. In this case the presence of the plants retards evaporation. It must be understood, however, that these figures refer only to plant stands in the open. They do not explain the conditions in cases of large areas of dense growths. It should be remarked, also, that in those cases where a large leaf surface was presented, as in the cases of those tanks containing Pickerel-weed, Arrow-head, and Cattail the results charted are

rather too small, since the cooler leaf masses collected a considerable amount of moisture in the fog which arose frequently during the night. This condensed moisture ran largely into the tanks, thus making the reading indicated too small, while some remained several hours on the plant surfaces before it was evaporated, thus retarding transpiration from the wetted parts.

The results so far obtained are but preliminary, and, while complete in themselves, they are in no respect final. Sufficient data are at hand to make further deductions, and these will be included in a later paper.

Ann Arbor, Mich., April 3d, 1911.

IS THE PREVAILING TEACHING OF THE LAW OF DIMINISHING RETURNS JUSTIFIED?

HERBERT ADOLPHUS MILLER.

It seems to be peculiarly difficult for men, whether in science, politics or religion, to give up a law or doctrine which has become a slogan to them, after it can no longer be justified. This is true of the law of diminishing returns which economists have considered to be fundamental to much of their reasoning. I have been able to find only one prominent economist of the present day who has made any definite attack upon this "Law."

Simon N. Patten, in the "New Basis of Civilization" says, "The law of diminishing returns was discovered by the most stupid body in England—a committee of the House of Lords. English agriculture at the close of the Napoleonic wars was so abnormal that anyone could see how the high price of food brought poor land into cultivation. A committee. even if it was stupid, could not but stumble on the pertinent facts that formulated the law. But their perception of it does not account for its subsequent vogue. The real question of control is: Why did a nation, naturally optimistic and in a period of rapid industrial advance, accept the hopeless doctrine and permit it to curb their thinking for generations? Why also do teachers in America, where notoriously it never has been in operation, hold devoutly to it and spend their time expounding a lame philosophy to their classes?"

Professor Patten does not follow this statement with a specific discussion as to his reasons, although his whole book is based on the principle of *increasing* returns.

Since I am not an economist but a dabbler, I feel a little uncertain how the position should be defended. I have looked carefully through the books of modern writers on economics and find that all lay much emphasis on this law. The following are typical definitions from prominent economist: Seligman in his "Principles of Economics" says that "The law of diminishing returns is * * * the foundation of the law of rent. A farmer will sometime reach a point where it will not pay him to add another laborer or another machine to his land because beyond the margin of profitable expenditure every additional 'dose' of capital or labor will mean a return insufficient to cover cost * * * The law of diminishing returns is universal and applies to everything that possesses value." Professor Seager in his "Introduction to Economics" says, "After a certain point has been reached in the cultivation of an acre of land or exploitation of a mine increased applications of labor and capital yield less than proportionate returns in product, it being understood, of course, that no important change is made in the method of cultivation or exploitation." Carver in his "Distribution of Wealth" goes more into detail and proves the law with mathematical exactness. In fact he is so clear that he seems to be proving the obvious. How-

ever he offers as an excuse that such proof would not be needed "had not certain writers seen fit to deny it because it did not harmonize with their views of economics, and certain would-be reformers to ignore it because its recognition would interfere with the acceptance of their reforms."

Such a reformer, I suppose, he would call Wm. H. Allen of New York who said in a recent article in the Annals of The American Academy that "When John D. Rockefeller said to the world 'There will never be enough money to do the world's uplift work,' he started in motion forces and doubts and compromises that will do vastly more harm to the south than the hookworm." The reason Mr. Rockefeller made such a statement was that he was obsessed by the law of diminishing returns which closes the door of hope, because as Patten indicates, hopelessness is inherent in a world of diminishing returns.

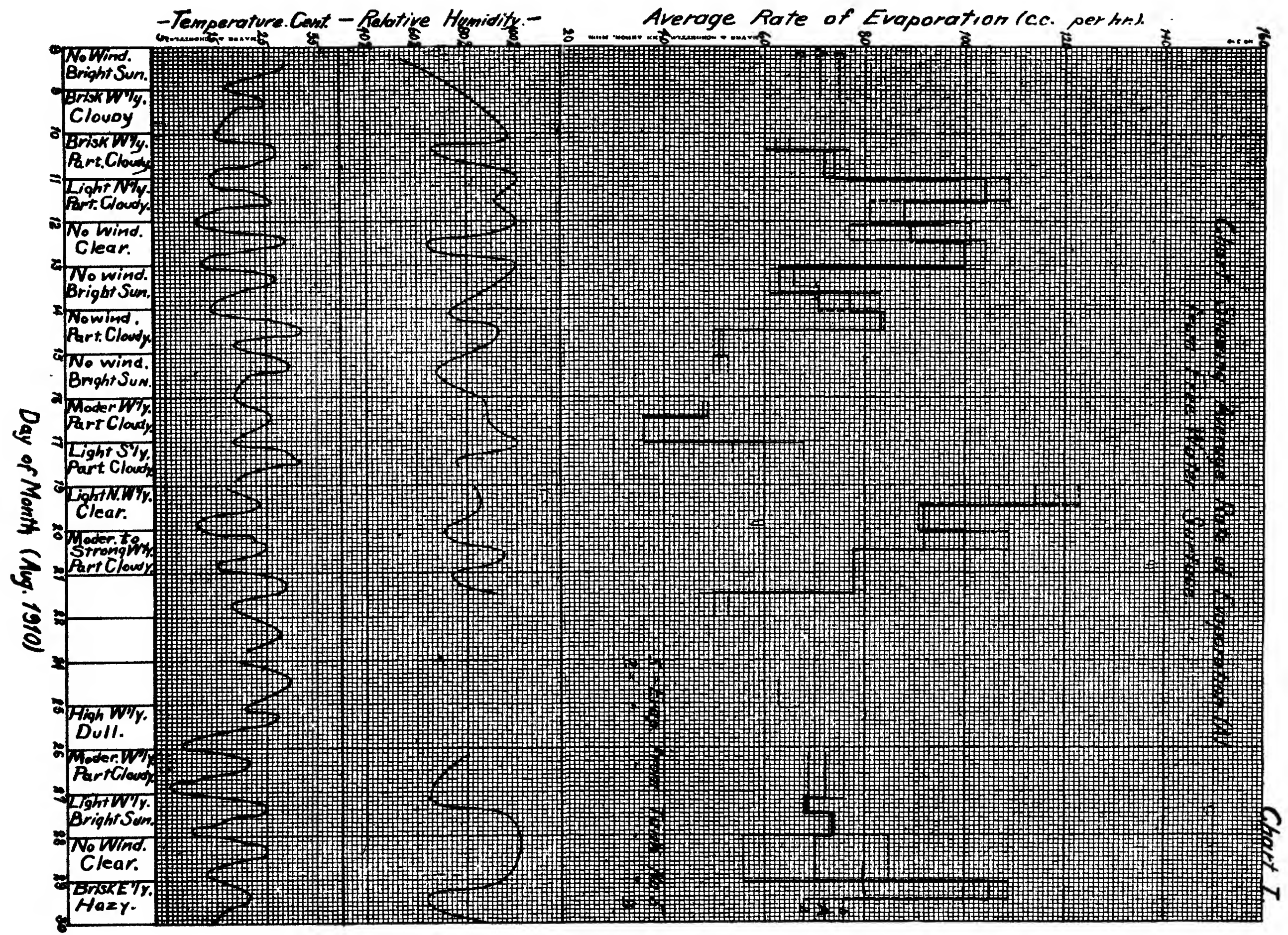
Many who argue for the truth of this law quote not only men of success like Mr. Rockefeller, but any business man or farmer who finds himself face to face with the law. The difficulty in both cases is that the individual is looking at production from his personal point of view, and not from the point of view of production as a whole. The economists, however, ought to see principles in the large.

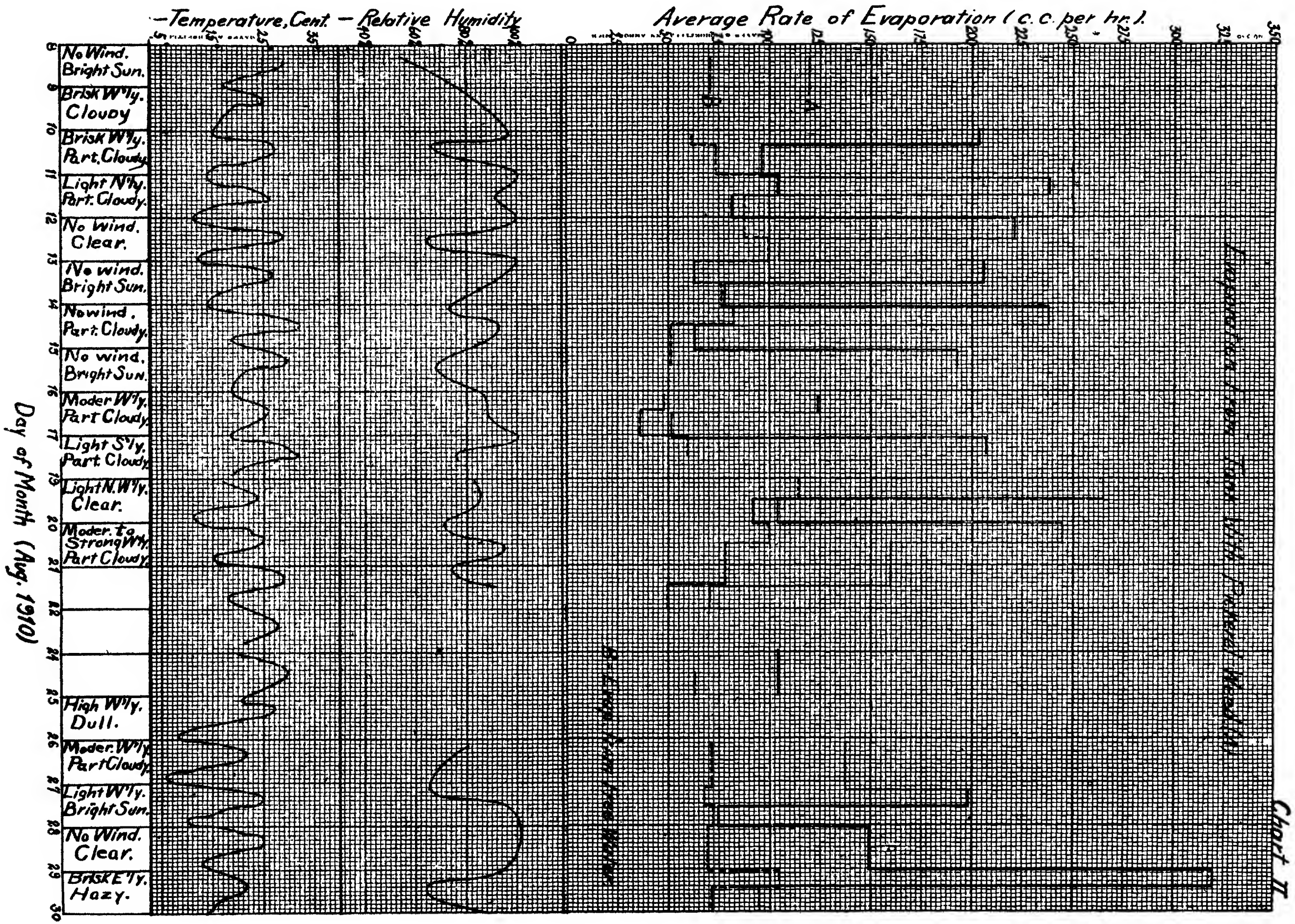
Scientific laws are much like creeds. Someone has an insight which he formulates, and for him and some of his successors the formulation seems to satisfy the conditions and the needs. So an economic law is the classification of a group of facts as someone's insight sees them; but as with the creed, men may make the fatal mistake of thinking it an eternal truth. There was a time when belief in hellfire was an incentive to morality, but now many of us succeed in getting a degree of morality when in the state of mind of the small son of a famous modern philosopher who asked his mother what hell was. She described it to him and at the close added, "But there are some who do not believe this." The boy replied, "Mamma, I am one of those." There was a time when the law under discussion had a vital meaning to the race, but I am one of those who think that a new formulation is in place, that here is a case where orthodoxy does not mean clear thinking.

The fallacy common to Seligman, Seager, Carver and the others is that of emphasising archaic conditions. Seligman, for example, was talking about equal "additional doses" of capital and labor; and Seager at the close of his definition said, "it being understood, of course, that no important change is made in the method of cultivation or exploitation." Now of what earthly good is a law for such conditions? If there is any indisputable fact in the world it is that important changes *are* being made in the methods of cultivation and exploitation, and, as for *equal* "doses" of capital and labor, who is so simple as to think of adding them? The question is not that of adding another cartload of the old fertilizer to a wheat field, but of adding some new fertilizer, exactly fitted to the wants of the crop, by which it may be doubled in quantity. It is not a question of adding a man with a sickle, but of adding a man with a modern harvester; not of sowing the old seed to yield tenfold, but the new seed to yield an hundredfold. Capital is multiplying so rapidly that it worries some people, at least, to know what to "dose" and invention multiplies the units of labor so fast that

they outstrip even our imagination. Now, to be sure, individual farmers must have practical methods of directing the expenditure of what capital and labor they have, and the law applies to them since each one is more or less in an eddy, just as I am in the matter of capital. I have little more than I had before the last multiplication of the capital of the world, but I am not so personal as to deny the increase. I claim to be part of the age of airships though I have never seen one and am no nearer an automobile than a state of covetousness. I try not to be like the woman in a small town who came to me after a lecture in which I had said that since three-fourths of the women in that village bought their bread from bakeries where it was made by men they could retain their power over bread making only by voting, she confidentially told me that she made her own bread, and hence did not see any need for women's voting. It seems to me that an economic law ought to be comprehensive enough to summarize the individual cases.

Professor Carver shows conclusively that in an individual case the law of diminishing returns may work exactly. He even shows that large scale production does not overthrow the principle; but he does not consider the pertinent fact of modern industry, that invention, organization and efficiency make constantly changing conditions, and that "equal doses" are out of date. He admits that the law is more evident when applied to stationary civilization, saying, "If civilization should remain stationary while population increases in density there would be a smaller per capita production because of the law of diminishing returns. The terrible reality of this law is witnessed by the overcrowding of those populations where, as in the unchanging East, civilization has become stationary." "I reply, "to be sure," but modern economics is neither history nor anthropology, and what should be taught in our colleges and to John D. Rockefeller, is a principle that applies to a progressive civilization. Again Carver says, "but with respect to the livelihood of a complex population considering all its industries in a mass, the operation of the law is not so clearly perceived." Again I say, "to be sure," because under such conditions it is not operating. And at the end of his long chapter, considering the relative productiveness of different sorts of labor, he states, "that nothing could prevent its (the former of the cited classes of labor) declining relatively to that of the latter class except a radical change in the system of industry, which would call for more than a proportional increase in the former class." The contention of this article is that there has been this radical change in the system of industry, that increases are becoming more than proportional and that we are not yet even in sight of the beginning of the end. I am perfectly willing to admit that the law of diminishing returns has an illustrative value, but it is taught in most courses and economic articles as though the world in which we live were about to suffer from its "terrible reality" as it would in a world of stationary civilization. At a recent large gathering of economists there were but two expressed exceptions to the opinion that immigration was about to become dangerous because the additional numbers would make competition too keen. They thus implied the fear that this bugbear law of diminishing returns will soon deprive us of enough to eat. The whole difficulty is a mistake of unjust and unequal distribution of wealth for an application of the law of diminishing returns. I presume that Mr.


-Temperature. Cent. - Relative Humidity. - Average Rate of Evaporation (c.c. per hr.).
Day of Month (Aug. 1910)
No Wind. Bright Sun.
Brisk W'ly. Cloudy
Brisk W'ly. Part. Cloudy.
Light N'ly. Part. Cloudy.
No Wind. Clear.
No wind. Bright Sun.
No wind. Part. Cloudy.
No wind. Bright Sun.
Moder. W'ly. Part Cloudy.
Light S'ly. Part. Cloudy.
Light N.W'ly. Clear.
Moder. to Strong W'ly. Part Cloudy.
High W'ly. Dull.
Moder. W'ly. Part Cloudy.
Light W'ly. Bright Sun.
No Wind. Clear.
Brisk E'ly. Hazy.
Chart I.



Temperature, Cent. — Relative Humidity
Average Rate of Evaporation (c.c. per hr.)
Day of Month (Aug. 1910)
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Brisk W'ly. Cloudy
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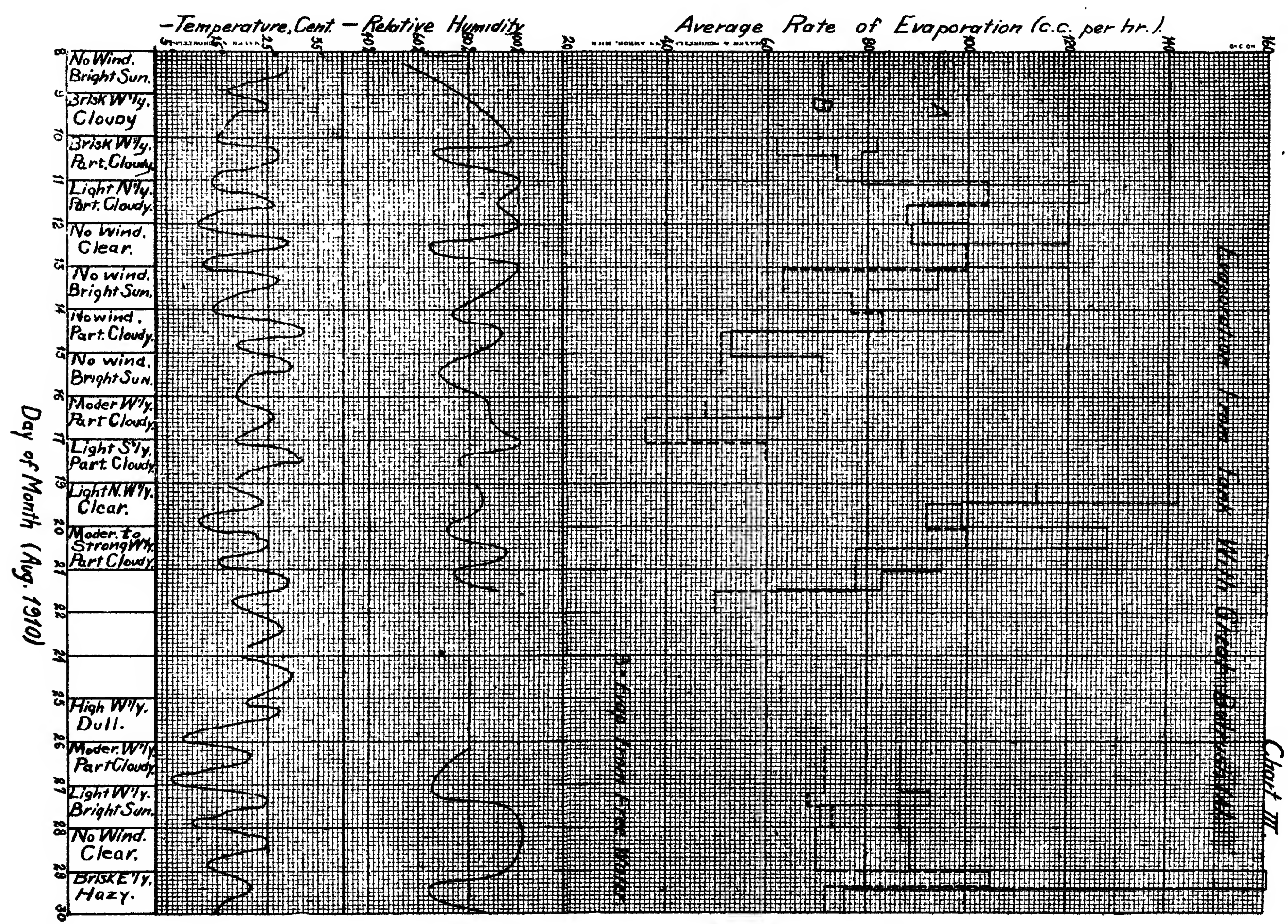
Chart II



-Temperature, Cent. - Relative Humidity
Average Rate of Evaporation (c.c. per hr.)
Day of Month (Aug. 1910)
No Wind. Bright Sun.
Brisk W'ly. Cloudy
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Light N'ly. Part. Cloudy.
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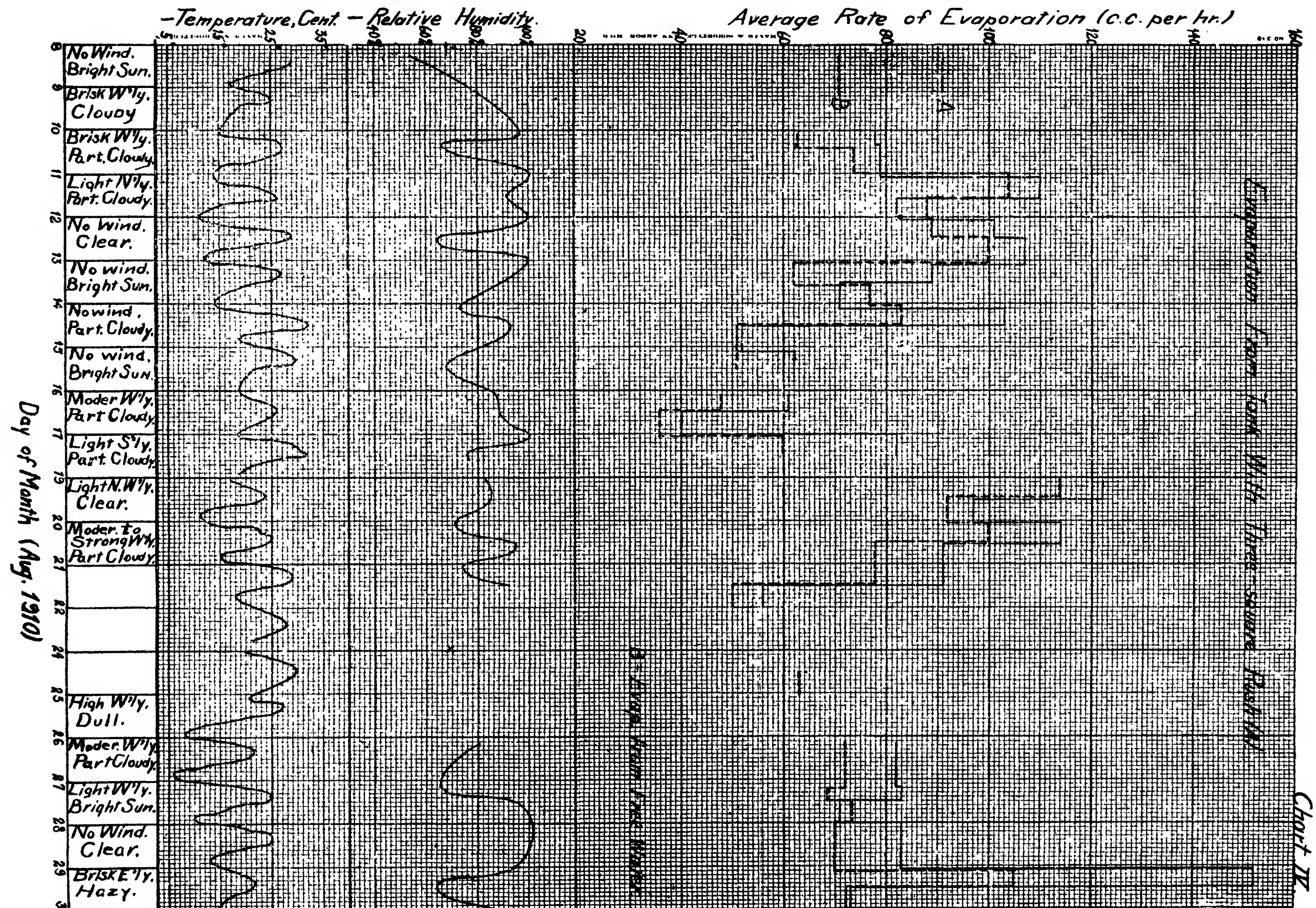
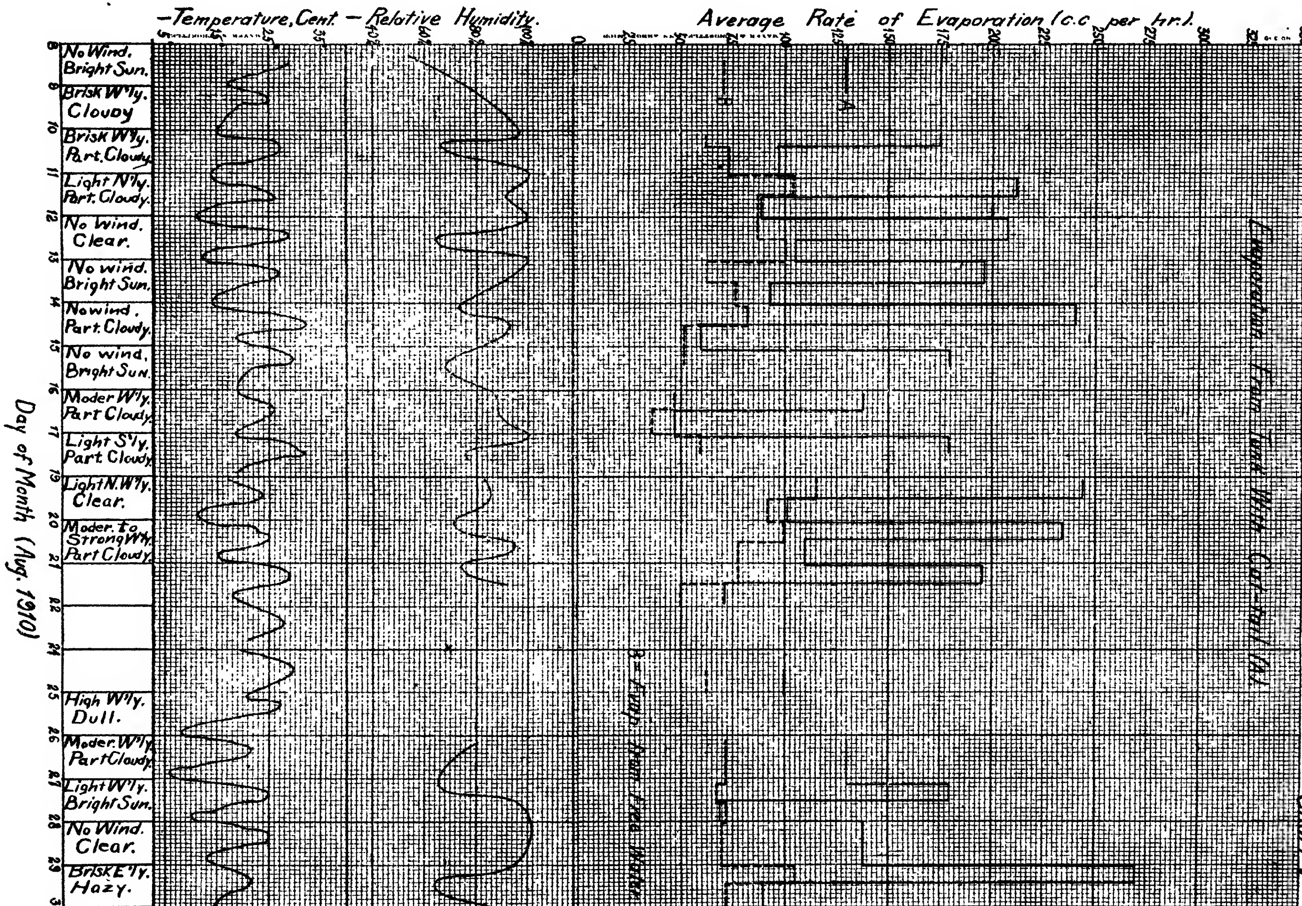
Light S'ly. Part. Cloudy.
Light N.W'ly. Clear.
Moder. to Strong W'ly. Part Cloudy.
High W'ly. Dull.
Moder. W'ly. Part Cloudy.
Light W'ly. Bright Sun.
No Wind. Clear.
Brisk E'ly. Hazy.
B
A
Evaporation From Tank With Green Bulrushes
B = Evap. From Free Water
Chart III.



-Temperature, Cent. - Relative Humidity.
Average Rate of Evaporation (c.c. per hr.)
Day of Month (Aug. 1910)
No Wind. Bright Sun.
Brisk W'ly. Cloudy
Brisk W'ly. Part. Cloudy.
Light N'ly. Part. Cloudy.
No Wind. Clear.
No wind. Bright Sun.
No wind. Part. Cloudy.
No wind. Bright Sun.
Moder. W'ly. Part Cloudy.
Light S'ly. Part. Cloudy.
Light N.W'ly. Clear.
Moder. to Strong W'ly. Part Cloudy.
High W'ly. Dull.
Moder. W'ly. Part Cloudy.
Light W'ly. Bright Sun.
No Wind. Clear.
Brisk E'ly. Hazy.
Evaporation from Tank With Three-square Rush (A)
B = Evap. from Free Water

Chart IV.



-Temperature, Cent. -Relative Humidity.
Average Rate of Evaporation (c.c per hr.).
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
No Wind. Bright Sun.
Brisk W'ly. Cloudy
Brisk W'ly. Part. Cloudy
Light N'ly. Part. Cloudy.
No Wind. Clear.
No wind. Bright Sun.
No wind. Part. Cloudy.
No wind. Bright Sun.
Moder. W'ly. Part Cloudy.
Light S'ly. Part. Cloudy.
Light N.W'ly. Clear.
Moder. to Strong W'ly. Part Cloudy.
High W'ly. Dull.
Moder. W'ly. Part Cloudy.
Light W'ly. Bright Sun.
No Wind. Clear.
Brisk E'ly. Hazy.
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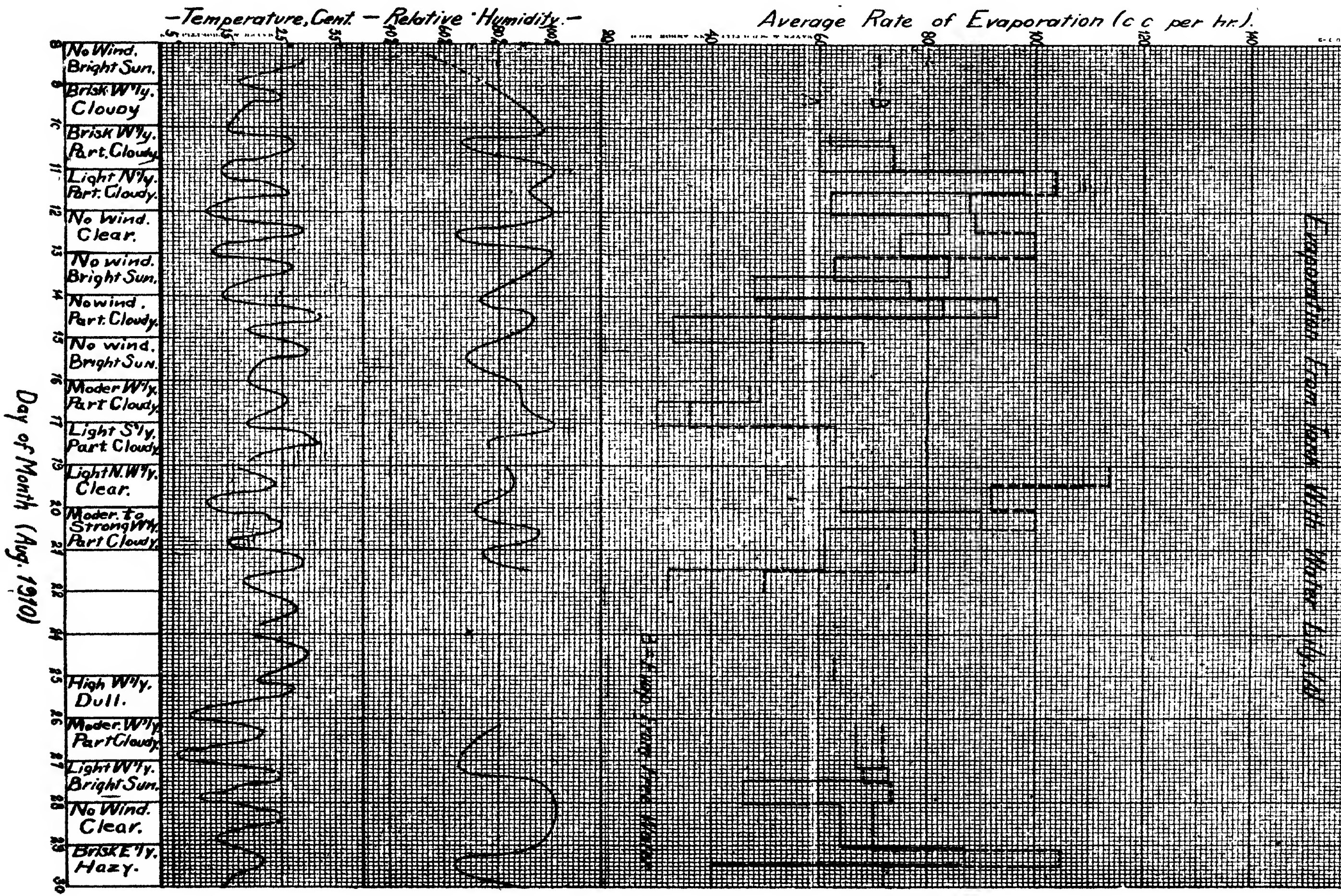
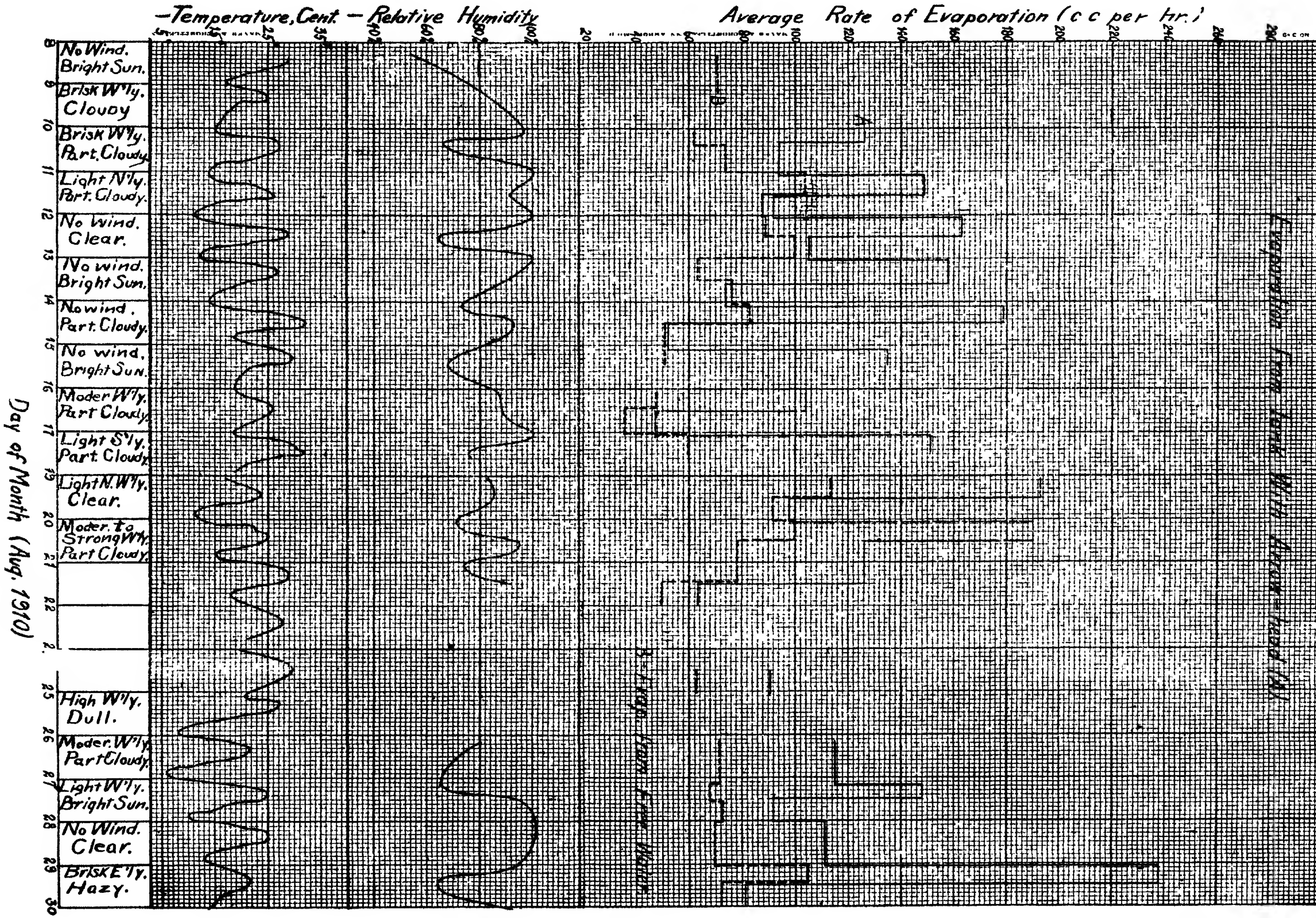
30
Day of Month (Aug. 1910)
A
B
B = Evap. from Free Water
Evaporation. From Tank With Cat-tail (A).

Chart V



-Temperature, Cent. - Relative Humidity.-
Average Rate of Evaporation (c c per hr.).
Day of Month (Aug. 1910)
No Wind. Bright Sun.
Brisk W'ly. Cloudy
Brisk W'ly. Part. Cloudy.
Light N'ly. Part. Cloudy.
No Wind. Clear.
No wind. Bright Sun.
Nowind. Part. Cloudy.
No wind. Bright Sun.
Moder. W'ly. Part Cloudy.
Light S'ly. Part Cloudy.
Light N.W'ly. Clear.
Moder. to Strong W'ly. Part Cloudy.
High W'ly. Dull.
Moder. W'ly. Part Cloudy.
Light W'ly. Bright Sun.
No Wind. Clear.
Brisk E'ly. Hazy.
B = Evap. from Free Water

Chart VI.



-Temperature, Cent. -Relative Humidity
Average Rate of Evaporation (c c per hr.)
No Wind. Bright Sun.
Brisk W'ly. Cloudy
Brisk W'ly. Part Cloudy
Light N'ly. Part Cloudy.
No Wind. Clear.
No wind. Bright Sun.
No wind. Part Cloudy.
No wind. Bright Sun.
Moder. W'ly. Part Cloudy
Light S'ly. Part Cloudy
Light N.W'ly. Clear.
Moder. to Strong W'ly. Part Cloudy
High W'ly. Dull.
Moder. W'ly. Part Cloudy
Light W'ly. Bright Sun.
No Wind. Clear.
Brisk E'ly. Hazy.
Day of Month (Aug. 1910)
B-Evap. from Free Water
Evaporation from Tank With Arrow-head (A)

Chart VII

Rockefeller's difficulty arises from the fact that any other method of distribution than that which has been contributory to his own successes is inconceivable. But economists ought to be able to see production and distribution at the same time, and in their totality.

The law of diminishing returns is intimately related to another famous and equally archaic economic law, viz.: Malthus' law of population. The substance of this law is that population tends to increase faster than the means of subsistence. There is something in this. It works in determining the number of *wolves*, but the last census report does not show *human* population in America confirming it. It is always a great satisfaction to find a single principle which will explain a condition; but we are becoming more and more convinced that social phenomena are the product of numerous forces and are not reducible to a single law. Malthus' law does not care whether a single family has many or few children, but whether population is increasing or decreasing. So the law of diminishing returns ought not to be limited to individual production but extended to production as a whole. It is quite true that the surface of the earth is limited in extent, and that the population of the earth is multiplying; but it is likewise true that the sun is losing its heat, and that sometime the earth will be uninhabitable. Any physicist might logically teach his classes the desirability that the human race accustom itself to the idea of being frozen out. But whatever the logic of the question it would and should make very little impression on the average healthy-minded individual. Our problem presents a very similar situation in which we may justly question whether a healthy-minded person should have any fear about the exhaustion of the proper number of food units that may be required. even if he is as far sighted as a Conservation Congress.

Soon after Malthus had written his book, his theory fell into disrepute because of the opening of the great interior plain of the United States. But thinkers soon saw that the principle was just as true as before, though the pressure of conditions was temporarily postponed. But now that we have come practically to the end of free land we seem to be nearer than ever to the threshold of the catastrophy. Even such a good thinker as Joseph L. Lee the Boston philanthropist feels it for in speaking about immigration he says "America is not infinitely large. It will in any case—in what, compared with the long future, must be regarded as a very short time—become so crowded that any further increase of the population—except at a comparatively slow rate can be made only at the cost of lowering the general standard of prosperity."

Land, however, is only one of the three factors in production. The incalculable additions to labor and capital in the last generation are so much greater contributions than more land could be that we are getting farther and farther away from, rather than nearer to the catastrophy. To return to the analogy of the sun's heat: it is of course true that the sun cannot continue to give off heat forever and remain as hot as before. But we have an interesting condition arising from the fact that though the sun is radiating its heat and thus diminishing its potential energy, yet the process of contraction which is taking place within the sun causes it to generate heat as rapidly as it is losing it, and while this is not a perpetual motion machine, for the purposes

of giving continuity of heat to the earth it is a perfectly satisfactory arrangement.

In like manner it makes no difference whether we get more land, or more productivity from the same land. Malthus said that population tended to multiply by geometrical progression, while the means of subsistence multiplied by arithmetical progression. This is true so long as the process is on an "equal dose" basis. But the conspicuous fact of modern times is that means of subsistence are multiplying at a rate which makes the multiplication of population look like the pace of the historic tortoise compared to that of Achilles, whom logic tried to keep from catching up. The logic of the law of diminishing returns is of the same type. Professor Carver shows that on a certain area of land twenty men can produce more per man than fifty though the total production of the twenty men is but 380 bushels compared with 650 bushels produced by the fifty men. As a matter of fact, in spite of Zeno's logic we know that Achilles could overtake the tortoise, and we likewise know that the 650 bushels are being produced, and that everybody has more to eat than formerly. If pragmatism is justified anywhere it is in such considerations.

A farmer recently told me that his father paid for his farm, fifty years ago, by carrying the mail on foot from Jackson to Grand Rapids, Michigan, one hundred miles, taking just a week for the round trip. All the information he carried could now be transmitted by wire in three minutes and the increase in the amount now transmitted per man in the mail service per week is geometrical progression under a tremendouse ratio. From this same farm his father hauled his wheat thirty-five miles to Jackson, taking approximately fifteen hundred pounds to the load, and requiring three days for the round trip. The Michigan Central freight can now transport wheat at least sixty thousand times faster; so that even though the most liberal division be made as to the part contributed by an equivalent of a single man and team now, a man's productivity is multiplied several thousand times. This is what we add instead of an equal dose. It may be claimed, however, that the introduction of the railroad brought a period of phenomenal increasing returns, but that they were not maintained. It is a fact that there has not been an increase in speed at all in proportion to the outlay devoted to increasing speed, and the law of diminishing returns seems herein to be finely illustrated. However, increase in transportation does not mean simply increase in speed, but much more it means number and extent of persons and things that can be transported in a given time. The number of people who have been brought into participation in transportation through the extension of the railroads, the increase in the power of locomotives, and the organization of the systems, demonstrates that the rate of progress has been continuous and of the same radical character as the change from stagecoach to express train. The exhibition of increasing returns is multifarious. During the Boer War I received the evening paper in an interior city at five-thirty p. m., and read of battles that occurred at six o'clock that same afternoon in South Africa. This was in Tennessee near the home of Andrew Jackson who fought the Battle of New Orleans after the war was over, and he did not then hear of peace until several weeks after it had been declared.

Increase in units of production does not consist merely of adding similar units. The saving of time by rapid transportation and intercommunication, the organization of capital so that it may be turned over several times where formerly it could perform but one service, makes a multiplication almost inconceivable, and everyone knows that in the land of invention and organization we are just beginning to open up discoveries for entry; while the division of labor and the application of the processes of efficiency-engineering give a potentiality to the present units of labor that is revolutionary. If we will project our imagination, keeping within the limits of reason, we can predict that the rate of progress will be continuous. It is quite conceivable that before this generation is passed we shall plough with power generated by the tides and transmitted by wireless processes, and that radium will be harnessed so that its incalculable energy can be used. With the tremendous increase in power the surface of the earth can be enlarged indefinitely. Why should not the plains of Europe and America be set on edge, or why should not artificial heat and light make possible several layers of productive soil, and certainly it can be employed all the year round. Already sanitation and invention are making possible the exploitation of the tropics, the really productive regions of the earth which hitherto have been undeveloped. Men can soon work where they cannot live continuously because they can commute in airships and change climatic conditions daily.

In the light of these facts and fancies let us consider the validity of Malthus' three principles: "1. Population is necessarily limited by the means of subsistence." This is more imaginative than dangerous, for, since "means of subsistence" is psychological as well as physical, it can not become a mathematical term. Nowadays our magazines are telling us that consumption of one-half or one-third of the "means of subsistence" would add greatly to our efficiency. I myself have made a definite reduction in the amount of food consumed and thereby multiplied my efficiency. Furthermore, it is undoubted that the science of nutrition is going to add many units to the food supply by subtracting the injurious, the wasted, and the unnecessary. This is the prospect before us, but in the meantime, with all the natural forces for multiplication of population active, nevertheless the means of subsistence has increased far beyond any proportions that have before prevailed. There is not the slightest evidence today that means of subsistence is directly affecting the increase in population.

"2. Population invariably increases where the means of subsistence increases, unless prevented by very powerful and obvious checks." This is so untrue today that it is not open to argument. In fact the portion of population having the greatest means of subsistence is standing still while the poorest furnishes the greatest increase. To be sure, the standard of life may be the line at which the force of the means of subsistence is defined, but this is a psychological line. The rate of increase is not lessened by any powerful and obvious check, and it is not beginning to keep up with the rate of increase of the means of subsistence. There never was a time when the world was as well fed as at the present.

"3. These checks and the checks which repress the superior power of population and keep its effects on a level with the means of subsis-

tence are all resolvable into moral restraint, vice and misery." Professor Patten in his last book, "The Social Basis of Religion," says, "Sin is misery; misery is poverty; the antidote of poverty is income." If the signs of the times means any thing, there is an increase in the world's income and a potential decrease in the world's misery through better distribution. Misery, then, with its accompanying vice cannot be the result of the law of diminishing returns, for returns are increasing.

Since the means of production are land, labor, and capital, and the methods of capitalistic-mechanical production increase the possibilities of the last two indefinitely, the resources of production show no more signs of being exhausted than the heat of the sun. Our census returns show that the population of the United States has increased 21% in the last decade, that urban population has increased even more, and that many of the best rural districts have lost population, and still there has been a disproportionate increase in the amount and variety of food. These facts make it absurd to argue that, as applied to production in the large, the law of diminishing returns is a factor to be considered. Why then in the teaching of economics, and in business is not the emphasis changed so that the fallacious Rockefeller point of view will not be attained? For obviously, as Patten says, our modern progressive civilization has passed the line of deficit and is capturing broader and broader fields of surplus. If we are going to retain a full treatment of this law and Malthusanism in our text books, could it not be labeled as an historical condition of which occasional relics may still be found? In answer to the argument that it is essential that we take the law as a starting point for the explanation of economic phenomena, I would reply that the explanation is good only for a condition that is stationary and looks to the past. May we not demand that in some way economists should frame a law in which, as in the law of the moving point by which the hyperbola is traced, the prophesy of the future should be as perfectly expressed as the history of the past and thus looking ahead, give us a true description of modern conditions of production?

Olivet College, April, 1911.

THE SIGNIFICANCE OF WAGES IN THE PRESENT LABOR PROBLEM.

EDWARD M. ARNOS.

The problem known as the labor problem may be properly divided into two distinct parts; that is, the conditions of the place of employment, and the conditions of the payment for the service of labor. I shall attempt to analyze the problem according to this definition, and deduce some conclusions from the analysis.

I.—THE CONDITIONS OF THE PLACE OF EMPLOYMENT.

Students of the pre-industrial revolutionary period agree that the laborer's problem then was to be able to produce enough. The conditions of the place of employment were well enough regulated so that none of the problems of today, such as accident and employer's liability, compensation acts, industrial diseases, long hours and excessive work, confronted them in the sense that labor is confronted by them now. I am not unmindful that the hours of labor were long, and that the sanitary condition of the place of employment was not excellent; but those conditions were under the supervision of the employees themselves, and were due not to negligence but to ignorance, and are therefore not condemned by the same principle. Their problem, namely, the problem of production, was solved by the introduction of the factory system. The thing that made it possible for them to produce more, so that the question of production was removed, was the thing that created our present labor problems. It transferred the laborer from one place of employment to another. His home ceased to be his factory. Along with that transference of the place of employment went his power to control the conditions of the place of employment, and also the power of society to justly determine the amount of product which each laborer added to society, in that, as the division of labor became more extensive under the factory system, no one could tell how much each laborer produced, as could be done when the laborer worked in his own home and produced the commodity to a finished product.

1. *Machinery*—The greatest of the forces of danger brought to the laborer by the factory is that by machinery. I have been unable to find satisfactory statistics of industrial fatalities due to machinery; but statistics collected by individual investigators, the Pittsburg Survey in "Work, Accident, and the Law," p. 14, shows the number killed by machinery in Allegheny County for one year as 526, as the number that came to their notice. Probably more occurred. Indeed that is an extreme case, but represents the importance of the laborer's problem with machinery. This does not consider the suffering and loss due to non-fatal accidents. The same investigation shows also that the great percentage of these accidents were preventable. That being the

case, the problem of machine accidents is a problem of short duration only, provided proper action is taken to procure a remedy.

2. *Poisoning*—A second problem is that of industrial poisoning. The cases of the use of phosphorus in the match indnstry and of lead in its industries are examples of this point. There are many kinds of poisoning in industry due to the use of poisonous substances in the manufacture of goods. The analysis of the cases of poisoning show them to be due to either ignorance or carelessness of the employee, the lack of foresight and care of the employer, and a few non-preventable causes of poisoning. These matters come to public attention when they become destructive to life and health. When they do come to notice, they take the usual course of legislation for remedy, or the dangers are removed gratuitously by the producers and are remedied within a reasonable period of time.

3. *Ventilation*—A third problem is that of ventilation. This is applicable only in certain industries, particularly in the manufacture of woolen and cotton goods, and mining. Upon the face of the question it is evident that any suffering due to the lack of ventilation is due to negligence. Machinery for systems of ventilation is so well known that there is no excuse for any plea against an efficient system of ventilation. The laborer suffers, but he suffers not because of the lack of any knowledge which society has, but because that knowledge is not used. To base the labor problem upon any such scheme would be to consider the problem as a very simple case, and unworthy of serious consideration.

4. *The Hours of Work*—The hours of labor which the laborer must perform has the most severe results. The effects which the number of hours of labor has upon the laborer are far-reaching. It may be the cause of some severe illness. It may be the cause of some severe accident. I have seen laborers go from the factory so completely exhausted by the hours of labor that they were unable to eat. A man in such physical condition does many things which he would not do when in the proper physical condition. He may stoop to wash his hands or rub his hands with a rag, not noticing the belt which is ready to grab him and tear off a limb or kill him. He may come in contact with some contagious disease, his physique not being in position to keep it off, due to an excess of labor; or it may be the direct cause of the degeneration of the character of the man. Not having time to enjoy any recreation, not having time even to develop the ordinary capacities of a man by means of having the ordinary acquaintance with current events, takes a man entirely out of communication with the world, destroys all interest a man may have in society or in himself. It leaves for the man nothing to lose by whatever acts he may perform. The only thing he has is the present misery. To relieve himself of it he takes to drink, and through the saloon affiliates himself with all of its institutions. That this is the usual course of a laborer laboring an excessive number of hours is needless to deny. Life bears it out in many cases of a group of employes with an excess of number of hours of labor.

This most serious portion of the laborer's difficulty arising from the conditions of the place of employment in hours is already largely solved through the eight and nine hour day in many of the industries. The

steel industry now probably presents the most serious result in regard to hours of labor. The seriousness of this problem is divisible into two parts: The exhaustion of the laborer due to long hours, a labor problem; and reduced wages in correspondence to reduction of hours, a wage problem. Doubtless the significance of this problem is greater in the latter case. Employers would have no reason to refuse shorter hours provided the wages per hour remained the same. The significance of this is wages, not labor.

II.—CONDITIONS OF THE PAYMENT FOR THE SERVICE OF LABOR.

1. *Statement of the Case*—It is to be observed that although the questions just considered are temporary and curable, when they are cured others are always present; so that there is that distinct feature of the place of employment, that it is not curable. We may remove all of the evils that confront us at present, but that would not be a solution of the labor problem in the place of employment; for as long as men associate with each other in work there will be some problem for them to solve. That, however, is not the case with the question of the payment for the service of labor, or wages. The present wage system is the natural outcome of the development which industry has gone through in the last few centuries. When men found that they could not produce enough separated from each other in industry, and it was found necessary for them to associate themselves together in the factory system so that they could produce more, there was no other way for them to divide up than to divide according to the product of each man's labor, as measured by competition between individuals producing the same thing. I understand that men sold their labor for money before the beginning of the Industrial Revolution; but take from Arnold Toynbee that such wages were always supplemented by land holdings and little was thus sold.

The development of the factory system extended the group of wage earners until now it is altogether the predominant group, in which group almost every man can be classified at some period of life or in some activity, and a very large number of men are to be always classified there.

2. *The Direct Evils of the Wage System as the Result of the Factory System*—It has brought about a severe class struggle on the part of the wage earners. This has increased in intensity year by year in proportion as the difference between the accumulations of the wealth of the wage earners and the reward to capital increases; that is, as wealth becomes more and more concentrated the laborers and poorer classes feel more clearly the contrast between their economic dependence and the economic independence of the rich class. The ill feeling and jealousy which is felt on the part of the laborer toward capital represents a great social struggle. It is distinctly a struggle of one class against another. This is expressed in our strikes, general industrial wars, individual antagonism between members of different classes, and local feuds as expressed at present in the wide spread "Black Hand" activities.

The day laborer is economically dependent upon one commodity, the most perishable of all commodities—labor. Under the present wage

system laborers must assume entire responsibility for the support of themselves and family, and it gives them only their labor with which to accomplish this support. By the very nature of that labor it must be spent and rewarded for at once, as it cannot be preserved. This necessities bargaining, and unless the laborer is a good bargainer or has adequate bargaining facilities he will not be able to gain from his labor satisfactory returns. So much depends upon his facilities as a bargainer that his ability to procure wages depends more upon his facilities as a bargainer than his ability as a producer. This condition has never been present in other systems of payment for the service of labor. In the cases of slavery and feudalism the laborer was economically free. The present system of the payment for the service of labor gives the laborer political independence and economic dependence. It has taken great force on the part of society to procure political independence for the great masses of the population. Some equal force should now be made not only to maintain political independence, but also to procure economic independence. It is maintained by many that collective bargaining through the organizations of laborers will accomplish this end. I will consider this at another point in this paper.

The present wage system puts labor to a disadvantage in treating their own cases. Firstly, because they are in large numbers; that is, their group is large, and the group with which they are treating is usually small. Whenever you have a large group treating with a small group, the large group is at a disadvantage because a small group can procure action quickly and focus their work more quickly, whether that be a case in court, or in open bargaining.

Secondly, capital naturally finds its support by different interests; the press finds it to their advantage to assist capital and capitalistic interests, thus shaping public opinion against its opponents.

Thirdly, because of being easily influenced by "scares." When employers want some particular thing and can get it no other way they are almost always certain to accomplish it by making some "scare" generally known. This is carried out in numerous ways; one case very clearly before the public now is that of the opposition which United States Steel is putting forth against labor unions. It is generally known about the plants that a member of a labor union will be discharged, thus scaring the men so that you cannot get one of them to talk labor unions until you have his closest friendship and confidence.

3. *Remedies*—Various schemes have been used to remedy in part or in whole the evils of the wage system just mentioned. Firstly, every state in the Union has some more or less adequate legislation to remedy the evils to some degree. Almost every state has some legislation relative to strikes, lockouts, and general labor disputes, as to their settlement either by compulsory or voluntary arbitration, and every state in the Union, I believe, has some kind of provision for aged, unemployed, and orphans, which affect their economic dependence.

We have a tendency toward legal proceedings in settlement of labor questions. Many employers are inviting their employees to consult with them in the settlement of questions which concern both classes. In some cases the employers even go so far as to invite employes' representatives to consult with them as to the substitution of labor-saving

machinery for older methods where the employment of a large number of men is in consideration. This growing tendency will result in a certain code or unwritten law necessitating the agreement of both employer and employee in all significant questions of labor.

Furthermore, we are producing definite and extensive written laws and court decisions. These are expressed in the work of the socialistic trend of the laws which the Socialists have been able to procure in Europe and this country, and in the various court decisions which have been handed down in labor disputes. The sum total of this written and unwritten law will in all probability be a great force in the solution of labor problems of the future.

Secondly, Cooperation and Profit Sharing—The extent of these is not great. The arguments for and against need not be presented here, as they are too well known.

Thirdly, Direct Result of Collective Bargaining—I wish to call attention to some things regarding the power and achievements of organized labor, directly resulting from collective bargaining. In the first case I contend that it is a debatable question as to whether or not collective bargaining has brought valuable results. I do not wish to minimize the value of labor unions and collective bargaining in the least, for it would be unwise for a labor sympathiser to disassociate himself from labor unions since they are the only working instrument the laborers have. But I am not convinced that such associations of workers have received valuable results from their activity in collective bargaining. It is observed that union laborers, in the main, have better places of work and slightly better wages. That cannot be conclusively proven, I think, but is generally accepted. That is not sufficient evidence, however, that collective bargaining has brought noteworthy results; for in many industries labor unions are weak or not organized, yet we have no cases of fourteen, sixteen, or eighteen hours of labor as was the case a century and a half or two centuries ago. The very fact that we have highly improved conditions in all employments would indicate that we would have had some large improvements in all industries had we not had collective bargaining; so that it is probably something besides collective bargaining which is bringing results to labor. It is admitted that the increase of capital has done a great deal in this regard.

It is not necessary for me before this body to defend the contention that the payment for the service of labor will increase as capital increases, supposing the supply of labor to remain constant. That being the case, our emphasis should be laid upon increase of capital, which can only come through saving; and this is the crucial point of this paper. Labor unions should teach their members to save. And that could well be done for a skilfully organized scheme would give the members of the wage earning class amusements to take the place of the expensive and ruinous saloon and affiliated institutions. So that the money spent in these departments could be saved with two beneficial results, the increase of capital, and the decrease of misery. Laborers would then find that their efficiency would be greatly increased by decreasing their dissipation. But as they become savers and capitalists their wages increase, not because they are able through collective bargaining to take something which some one else has or should have, but are able to take something additional because there is a greater demand for labor and because

their increased efficiency has enabled them to produce something additional. The results of such exploitation of human toil and its possibilities are unlimited. What a man can do under the proper environment cannot be estimated. And if the labor unions would set themselves to the task of developing their members and cultivating the spirit of saving in them, no one can estimate the result.

The first probably beneficial result would be the elimination of the wage earner, since by saving he would eliminate himself from the wage earning class in proportion as he saved. He would then become the employer and the employee as he was before the Industrial Revolution; he would own industry. The labor problem as we know it now would then be solved, as no one would receive wages, all would receive profits and interest. All would receive profits, too, in such a way that they could accept them. Wage earners now cannot accept profit sharing because they are not able to run the chances of uncertain profits; but laborers then would be able to run the chances of uncertain profits because laborers then would be capitalists with accumulated funds.

Some labor sympathizers claim that such a scheme would not be practicable because there is a time in every laborer's life when he cannot save anything, as he is out of employment. Many contend that such a scheme as proposed is idle speculation and does not bear on the labor problem in any important degree. They contend that the labor problem is long hours, poor ventilation, industrial accidents and diseases, nonemployment, etc. I have attempted to give the significance of these questions in the first part of the paper and will not comment on them further.

I admit that some will not be able to save all of the time nor is this necessary. They are not able to save at present for some or all of the reasons mentioned in the preceding paragraph. The point of this paper is that in the degree that the laborer saves these evils will be remedied.

Nature of the Saving Scheme.—It is not necessary for me, nor possible in this paper, to give a workable scheme for every industry. It is sufficient to say that Massachusetts has conidered this matter of sufficient importance to attempt a working scheme in connection with their savings banks. The Railroad Trainmen are attempting some things in this line in a small and voluntary way. Doubtless many different organizations have some provisions for industrial saving. The new "postal saving bank" might help some, but ónly in a small way until it becomes compulsory. Industrial insurance as now conducted by the insurance companies is in the same class as institutions for voluntary savings.

Labor unions should conduct this institution because in them the compulsory feature could be carried out with little or no extra expense—one objection to the present form of industrial insurance.

Olivet College, April, 1911.

THE THEORY OF THE GENERAL PROPERTY TAX IN MICHIGAN.

W. O. HEDRICK.

Michigan, like most of her sister states, relies mainly upon the general property tax for the means with which to defray the expenses of government. This tax came into use early in the territorial period of our history but its proceeds were devoted wholly to the needs of the local governments throughout the entire length of this time. The "separation of sources" scheme of taxation, which now finds so many advocates, was indeed anticipated by the early customs in vogue in this commonwealth with regard to revenue matters and the present partisans of the "separation" method who would introduce this reform into the Michigan financial system may properly urge that "separation" is a re-establishment instead of a novelty. The new state government of 1836 found the specific taxes, from which the territorial establishment had hitherto drawn its chief support, inadequate to supply the wants of an independent authority and early in its history resorted to the tax on property, thus sharing with the local divisions the revenues from this impost.

The laws concerning the levy upon property in Michigan have undergone an enormous amount of legislative amendment and rearrangement —the general tax on property itself having been re-enacted as a complete piece of legislation no less than fifteen times during the history of the commonwealth. The intervals of time which have separated these enactments have varied greatly in length since not infrequently two legislatures in succession have adopted complete taxing statutes, although in other cases ten, fifteen and even twenty years have elapsed between the appearances of these new measures. The first of these general imposts upon property became a law in 1820, the last in 1893.

Each one of these taxing laws has followed essentially the same model so far as its structure is concerned and in all of them the provisions with regard to levying the tax and collecting it—in a word the administrative methods—have comprised nine-tenths of the statute, and have furnished practically all the serious tax problems with which Michigan has been confronted. The theoretical features of property taxation in Michigan, it is conceived by this paper, is found in the remaining portions of these statutes and has to do with the legislative intent as to who should pay taxes and upon what property and to what jurisdiction. In brief, the *design* of the statutes with regard to taxation matters rather than the actual accomplishment under their administrative provisions or even the nature of these administrative provisions, is the subject which we have undertaken to discuss as taxation theory and an examination of all the different taxing laws has been made with respect to what property it was *designed* should pay taxes through whom and where to show the character of this theory from time to time.

Every general taxing law has invariably classified property for taxation purposes as real estate or as personal property and "cash value" has been the invariable legal measure of the taxableness of properties found in both of these classes. In early days a rated tax was the impost used by the state government for the defrayment of its own expenses but since 1853 both the state authority and the minor divisions have alike made use of an apportioned tax as the proper method of levying their exactions.

All general taxing laws have always included among their objects every kind of non-exempted real estate situated within the commonwealth and have always associated together land and all non-exempted "buildings and fixtures thereon and appurtenances thereto" in their definitions of the term realty. This kind of property has furnished by far the major portion of the state's assessable resources, although in early times the reservations by the federal government in the enabling act by which Michigan became a state, of all federal realty from the operation of state taxes removed at once three-quarters of the Michigan lands acreage from the operation of the property tax.* This enforced renunciation for taxation purposes of so large an area furnished a theme for complaint to the early state authorities which was only appeased by the gift of many millions of acres to the state and the prompt disposition of the remainder to private proprietors under whom it became immediately taxable. By 1874† only a twelfth of the realty of the commonwealth remained free from taxation through its relations with the general government and much of this has since come into private hands.

All taxing laws have likewise invariably regarded personal property as liable for the needs of government, and a definition of this kind of property has been found in each of the taxing laws since the time when the receipts from this tax ceased to be used exclusively for local purposes. Moneys, chattels, boats and vessels, corporate shares or stocks, annuities and credits less indebtednesses have at all times been included within these definitions although none of these terms have maintained the same meaning throughout each of its uses save moneys and boats and vessels. Personal property, too, itself, has been an expansive term since at different times new items have been inserted within its definition and our research into legislative design in order to be complete will require an inspection of each of these constituents of personalty as well as an enumeration of the different items which have in later years been added to the list.

The taxation of corporate shares or stocks in this State by means of the general property tax has suffered much restriction through the Michigan plan of employing specific taxes as the means of securing a public revenue from the larger corporations. All corporations originally made their contributions through this form of taxation and the important ones continued to do so until a decade since and even now are taxed by a special corporation tax. The greater number of the residual corporations too—those not levied upon by specific methods—have submitted to the general property tax exactly as have private individuals—paying their taxes upon assessments precisely as do real persons—so that few oppor-

*Cong. Rec. Sen. Doc., No. 32, 1838.
†State Aud. Rep. 1874, p.

tunities indeed have existed for taxing stocks in domestic corporations without inflicting an unjust double taxation.

The personal property tax on stocks and shares came in this way very early to denote a tax on stocks and shares in foreign corporations only, and this fact is recognized by a statute of 1853 which provides for the taxation of shares or stocks in all railroad, turnpike, canal and other corporations out of the state which are owned by inhabitants within the State. No alteration of this situation has taken place until the present time with the single exception that banking companies are taxed through their shares of stock and this outcome was brought about by the rule of taxation laid down by the federal government as to the way in which national banks should be taxed and the further provision that the method employed should not be different from that used in taxing state banks. The shares in foreign corporations therefore, except in the case of banking shares, alone develop almost the entire sum which is received from this form of personalty.

That classic bugaboo to a general property tax—credits—appeared early among the items of personalty in our taxing laws. At all times too, net credits only have been taxable since always deductions have been permissible to the amount of ones indebtednesses. The earlier taxing laws limited strictly the credits which were subject to taxation to those which resulted from time transactions in money or goods, but a statute of 1882 provides an omnibus clause under which all credits, even those due from corporations are assessible. Under this provision, notes, mortgages, bonds, and bills and accounts receivable become taxable and public sentiment has run strongly in the direction of bringing all these classes of property to the assessment rolls. Land mortgages, indeed, have proven themselves especial causes of discord in the various agitations which have taken place in favor of securing more revenues from taxing credits. This distinction has resulted from the fact that land mortgages are objects of record and also because of the large aggregates of this sort of property which now exist. In 1891 a mortgage tax law was adopted by which credits of this sort were considered as an interest in the land, which was subject to the mortgage, but before a fair trial of this method of taxation could be had a rival legislature repealed the law. Once again in 1901 a mortgage taxation law was adopted by the legislature but was vetoed by the State executive on account of certain administrative defects.

The Hercules of the personalty group of properties—if the term herculean be not indeed, wholly a misnomer in describing the revenues which have come from any of these taxable—is the class of things known as chattels. The abundance and the tangibleness of this sort of property gives it second place to realty only in the amount of tax receipts which have been developed while the zeal of the legislative attack upon this sort of personalty may be gathered from the care which has been exercised in defining the scope within which taxable chattels were to be found. The earlier statutes limited themselves to the simple statement that chattels wheresoever they may be are subject to assessment but the laws of 1893 elaborated this simple phrase into two provisions: the first providing for the taxation of chattels within the state and the second for the taxation of chattels in other states if owned by inhabitants of this commonwealth.

The term chattels has itself undergone pronounced expansion in the successive taxing laws which have been adopted both as to the number and as to the variety of things to which it has been applicable. The earliest taxing law, for example, excluded from among the list of things which would be commonly thought of as chattels, young domestic animals, sheep and all property not subject to the laws of execution. These were all reincluded, however, among the things considered as chattels by a subsequent law. The law of 1853 excluded wearing apparel from among the things called chattels, that of 1869 family pictures, of 1891 pensions, while the last tax enactment, that of 1893, threw out all of these and also school books, private sewing machines, libraries and re-exempted young domestic animals from the assessment list. But frequent as these excisions have been, the term has been depleted but slightly of its content through exemption and the present taxing statute groups no less than twenty familiar classes of property under the title of chattels while the personal property tax receives its staunchest buttressing as a part of state tax systems through the amount of revenue which can be collected from this sort of property.

The growth of the common city street car lines into the familiar interurban electric systems was the cause of the most serious anomaly in the classification of personalty within our statutes. After the abandonment of specific taxes upon these properties in 1882 the street car companies became liable for taxation upon the ordinary assessment rolls although the usual rule that "fixtures and appurtenances to real estate must be taxed as realty was everywhere abandoned because the typical property of street car companies is fixed to the non-taxable public streets. Car tracks, switches and street cars were assessed under these circumstances by a species of mutual agreement as corporate personal property and no injustice was done since the same rate of taxation is usually applicable under the same taxing authority to both personalty and realty. But with the strife of competing jurisdictions as these lines were extended as interurban roads into the country under the same circumstances of traversing public property, a more formal arrangement was necessary and the law of 1893 formally legalized the absurdity of regarding car tracks as personal property and further violated our tax customs by allowing this personalty to be levied upon by the jurisdiction under which it is found. No unusual features have developed with regard to the other recent additions to the personality definition such as forest products, produce, seeds, grains and nursery stock, and all of these have been simply incorporated into the assessment lists with the twenty or more other classes of goods which come under the name of chattels.

The actual amount of property which has developed revenues for the support of government from time to time has been far less extensive than the realty and personalty classifications just referred to would suggest. This has been the outcome from exempting many different property owning organizations, institutions and persons from the payment of taxes. The most important of these remissions are those which government has given itself through absolving from tax payments all public property throughout the State. The earliest of our taxing laws left the belongings of the local governments untouched through specific exemption while the later laws have extended the same privilege to the properties of the commonwealth for the reason in both instances that it is obviously in-

expedient for government to take from itself what it must necessarily again restore. This exemption of school establishments, public buildings, parks and other municipal properties has made no inconsiderable reduction of the total valuation within the State which would otherwise have found its way to the assessment lists. Closely following these reservations of governmental property in order of importance come the exemptions of the property of the general public utilities companies owing to the fact that these companies have usually paid specific taxes upon their earnings or upon some other element and the demands of justice require that they should not be doubly taxed. The worth of these properties, and therefore the measure of the exemption, which has prevailed, has varied at different periods but at all times their absence from the customary assessment roll has been a subject of complaint from local authorities who have missed the contributions which would otherwise have benefited the local treasuries. In 1899 the "great appraisal" developed a value in these properties which equalled almost a sixth of the amount of the assessed valuation of all other property within the commonwealth. It may safely be estimated that the reservations of this sort commencing with railroads and plank roads, in 1846, and subsequently extended to copper, iron and coal mines, telegraph and telephone companies and street car lines, and to others has at all times equalled fairly approximately this proportion of the property value within the State. An examination too, of the taxes developed from the specific taxes in comparison with those developed from the general property tax shows a disparity at all times of only a little less than one-quarter as much from the former as from the latter and this tends to confirm the estimates of the relative values of these properties as based upon the "great appraisal."* The property of these companies, although no longer paying specific taxes is still exempt from the general property tax since its assessment at present takes place under a modified property tax.

The organizations and institutions which came next in the extent of the benefits received through being allowed immunity from taxation are the churches and religious societies and charitable, benevolent, literary, library and scientific associations, etc. The similarity in the ends which are striven for by these bodies and those for which government itself strives is sufficient reason for omitting their property from the assessment rolls, although the propriety of this action has been frequently questioned by different legislatures. The taxing laws of the territorial period designated simply the property of churches and religious bodies as being exempt from taxation but the later statutes have been much more specific and have included the furniture, the rights to pews, the parsonages and the lands upon which churches stand as coming within this tax immunity. Burial grounds and the charitable homes of secret and fraternal societies have also come to enjoy a similar exemption:. The memorial societies such as Grand Army posts, sons of veterans, woman's relief corps, etc., are also comprised within the same class.

A great variety of persons have at different times too been the beneficiaries of the exempting clauses of the taxing laws some times for obvious reasons and again for no easily assignable cause. For example, persons having household furniture worth in value less than $200 or

* The Appraisal in 1900 of the railroads, express companies and similar public utility properties by the Cooley-Adams commissions.

spinning wheels and weaving looms, worth less than $50 or libraries and school books not to exceed $150 or ten sheep or two cows or five swine, fuel for six months or arms and accoutrements or any one or more of these items might claim under the law of 1853 immunity therefore from taxation. The property of Indians was exempt until the law of 1869 and that of alien Indians until the present time. Since the law of 1893 mechanics and farmers have been exempt from paying taxes upon tools and implements not to exceed two hundred dollars in value and at all times since the property tax was first used for State purposes indigent persons have been free from paying taxes upon their personal property and since 1893 upon their realty also.

The State has also made use of the taxing laws with more or less success for the accomplishment of many other purposes than those which have been strictly fiscal and in this way much property has been relieved from contributions to government. The social or industrial ends which the State has had in view have usually been striven for by the enactment of tax exemption laws by which the activities favored by government were relieved from the depressing effects of paying taxes. Mulberry trees for example, were relieved from taxation by an early territorial law in order to give a spring to the silk industry. Sheep were put upon the free list by a law of 1833 to encourage wool growing, salt and salt mills by a law of 1857 were freed from tax payments and indeed the industry became the recipient of a bounty. Sugar manufacturing plants and sugar cane and sugar beet growing came upon the exemption list in 1881, agricultural societies the same year, and in 1889 shares in building and loan societies. The sum total of the property which has thus been freed from taxation by these means is doubtless small but the full proportions of the deductions which have been made from general property could not be shown without some reference to these special immunity acts.

The devastating encroachments of exemption provisions upon the nominally taxable general property is partially balanced on the other hand by the additions in the law of 1846 of the ordinary business corporation to the list of taxpayers whose property should be listed upon the assessment roll. This provision for the development of a revenue from the ordinary business company seems indeed to have been an anticipatory measure since at the date of its enactment few, if any, corporations for gain except those within the bank, the mining, the railroad and river navigation industries—all of which were specifically taxed—had come into existence. The future was doubtless clearly foreshadowed however by the growing multiplicity of these latter companies as to the future probable character of business ownership and control so that this early designation of corporations for taxation was not unwarranted nor untimely. The corporation tax of 1846 has been the basis for similar provisions in each general taxing law from that time until the present.

The State tax commission in its first report criticised severely the method of taxing corporations upon the assessment roll in the same way that human property owners were taxed as a method which was inadequate and ineffective and makes a special charge of self-seeking against this class of tax payers. "In no instance," says the report, "has the commission found any obstacles placed in its way by individuals. Every contest against the commission and nearly every complaint has had its origin in some one of the great corporations whose assessment has been re-

viewed. This was not because they were assessed beyond their cash value, but because their long escape from equal taxation had led them to believe, or at least assume, that they had prescriptive rights to exemptions."*

The first fruits from the agitation thus engendered for increased revenues from corporations was the enactment of a law by which a practical method was provided for securing reports from these creatures of the State. Utilizing the increased fund of information concerning corporate business which came to it as a result of these reports the State tax commission has distributed material regularly to the local assessing officers by which they might more properly place corporate property upon the assessment rolls than had formerly been the case. There can be little doubt now but that the circulars which the commission has distributed have been very helpful in enabling the local officer to perform his work more efficiently.

An associate benefit which has come from this agitation for the better taxation of corporations has been the development of the legal right to assess the intangible property of these companies. The successful resistance on the part of the Detroit Common Council to the suit of the Citizens Street Railway company which sought to prevent the assessment of four millions of dollars of additional value against it on account of its franchise and other intangible property established the lawfulness of attacking this common and highly valuable species of wealth by assessing officers. The rule of taxation for foreign business corporations doing business within the State both with regard to the State franchise tax and also with regard to assessment by local officials is in no essential respect different from the rule applicable to the domestic kinds except in such minor respects as develop in the application of the tax. Vessel owning companies and private banking companies are required to make different reports from those exacted from other companies but in no other respect does this taxation differ from that of ordinary corporations.

The jurisdiction to which property shall be subject for taxation purposes or as quaintly expressed in the early taxing laws "Where property shall be taxed," has carefully been explained in each of the successive statutes. The situs question in the actual administration of a tax is of serious significance both to the property which is to be taxed and also to the authority which is to impose the levy. To the former the evils of double taxation are threatened if the competency of the jurisdiction to which it is liable is not clearly established while the latter is in danger of losing its revenue resources if the fiscal obligations of property are not clearly defined. This problem of localizing property for taxation purposes is one of constantly increasing significance too, owing to the growing complexity and extensiveness of the taxable involved and the theory of taxation is no longer complete without a discussion of situs consideration under such strange terms as "division of yield," "segregation of sources," "centralized administration," etc.

Michigan has had an almost unique experience in dealing with the matter of situs privileges and responsibilities through the fact that it has been her policy to persistently ignore at all times situs considera-

*Rep. of State Tax Com. 1901, p. 31.

tions in the collection of taxes from the great public utilities corporations such as railroad, telegraph and telephone and express companies. The explanation of this situation is to be found of course in the peculiar nature of the taxes to which these properties have been subjected —specific taxes—and the alleged objectionableness of the plan has very often aroused severe public criticism. The condemnation of this scheme of taxing public utility companies as units has come usually from the cities where the offices and warehouses and other terminal facilities of such companies are situated and where water, sewage and police facilities and fire protection must be furnished with no reciprocal payments in the form of taxes from the properties benefited in return. The criticism of this Michigan plan of disregarding situs consideration in the taxing of public utilities companies is most fully set forth in the constitutional convention of 1850.* In recent years the plan of distributing the revenues from these properties to the public school fund and upon a scheme of apportionment which allocates to the cities a large proportion of the entire fund has apparently furnished some recompense to these municipalities for their otherwise unrequited expenses.

The laws for taxing general property in this State have invariably assigned to realty a taxation situs within the township or other place of situation upon the theory doubtless that these jurisdictions are in need of the revenues which may be developed from realty and they are also the sources from which the chief benefits will come for which this taxable should make recompense. The fiscal responsibilities of personalty on the other hand have with equal uniformity been allotted to the jurisdiction within which the owner lived although the influence of the benefit theory of taxation has been powerful in creating many exceptions to this rule. Personalty such as goods or cattle, for example, which is used or maintained in connection with property which is situated in some township other than that wherein the owner resides, must pay taxes at the place of location upon the theory doubtless that it is here that the chief benefits of government are received. Buildings erected upon public lands of any sort and owned by private owners and also the personal property of non-residents of the State are for similar reasons liable to the jurisdictions in which they are found. On the other hand shares in bank stock follow neither of the rules for localizing personalty which have been given but are assigned to taxing jurisdictions almost arbitrarily and in a way dictated by experience.

The tax obligations of corporations amenable to the assessment roll are with respect to realty identical with those of human tax-payers although in the case of personalty their place of business is the determinant of their jurisdictional responsibility instead of place of residence as in the case of human beings.

The use of property as a measure of faculty it may be said in conclusion has become strongly intrenched in the beliefs and practices of the State not only as exemplified by the general tax which has been described but also by the modified property tax which is applied to general public utility companies and also by the use of still a third property tax—the one which is applied to inheritances.

East Lansing, Mich., April, 1911.

* Con. Con. Debates, 1850, p. 750.

REPORT OF THE LIBRARIAN OF THE MICHIGAN ACADEMY OF SCIENCE FOR 1910-1911.

The principal work of the librarian this year has been the distribution of reports. The twelfth report was received in September (1910), and was shortly afterward sent out to the members and exchanges. In addition to this, the sets of seven old members and two institutions that had not received certain volumes were filled out, and fourteen volumes were sold.

Aside from this work, a card catalog of members who have received reports has been prepared, so that we now have a record of every book that has been sent out to them. By referring to this catalogue we can tell at once whether or not a member has received a certain report, and if not whether this was owing to the fact that the dues were not paid for that year.

The extra volumes of the report in the library of the State Department have been transferred to Ann Arbor, and an inventory made of the present reserve stock. The number on hand is shown in the following table.

TABLE SHOWING NUMBER OF COPIES OF EACH REPORT IN THE RESERVE SERIES ON APRIL 1, 1911

Report.	Year.	Number of copies.
First	1894-99	24
Second	1900	371
Third.	1901	480
Fourth	1902	539
Fifth	1903	418
Sixth.	1904	435
Seventh...	1905	147
Eighth ..	1906	217
Ninth...	1907	188
Tenth	1908	189
Eleventh	1909	258
Twelfth.	1910	285
Total...		3,551

There are, at the close of the year, 570 institutions on our exchange list. This is one less than was listed in the last report. Nine names have been dropped from the list, either for the reason that the institutions were defunct or because they were already receiving the reports under another name. Eight names have been added to the list—the University Library, Edgbaston, Birmingham, England, the Manchester Geographi-

Address: Care University of Michigan Museum, Ann Arbor, Mich.

cal Society, Manchester, England, the Museo Nacional de Historia Natural, Mexico City, Mexico, the Society for the Development of Experimental Science, Moscow, Russia, the American Midland Naturalist, Notre Dame, Indiana, the State Board of Forestry, Indianapolis, Indiana, the Department of Mines and Agriculture, Sidney, New South Wales, the Bureau of International Catalogue of Scientific Literature, Smithsonian Institution, Washington, D. C.

The whole list of exchanges is appended to this report.

LIST OF EXCHANGES.*

Aberdeen Natural History Society, Aberdeen, Scotland.
Aberdeen University Library, Aberdeen, Scotland.
Academia de Ciencias, Mexico City, Mexico.
Academia de Ciencias, Médicasy Fisicas, Havana, Cuba.
Academia de Ciencias Naturales, Lima, Peru.
Academia Nacional de Ciencias, Cordoba, South America.
Academia Polytechnica, Oporto, Portugal.
Academia Real das Sciences, Lisbon, Portugal.
Académie de Metz, Metz, Lorraine, Germany.
Académie des Belles-Lettres, Sciences, La Rochelle, France.
Académie des Sciences, Art et Belles-Lettres, Dijon, France.
Académie des Sciences, Belles-Lettres, Lyon, France.
Académie des Sciences, Belles-Lettres et Arts, Rouén, France.
Académie des Sciences et Letters, Montpellier, France.
Académie des Sciences Inscriptions et Belles-Lettres, Toulouse, France.
Académie Nationale des Sciences, Caen, France.
Academy of Science, New Orleans, Louisiana.
Academy of Natural Sciences, Philadelphia, Pennsylvania.
Academy of Natural Sciences, St. Paul, Minn.
Accademia delles Scienze dell' Istituto, Bologna, Italy.
Accademia delle Scienze, Lettere ed Arti, Genoa, Italy.
Adrian Scientific Society, Adrian, Michigan.
Aix University Library, Aix-en-Provence, Bouches du Rhone, France.
Akademija Umiejetnosci, Krakau, Austria-Hungary.
Alabama Geological Survey, University, Alabama.
Albion College, Library, Albion, Michigan.
Alma College, Library, Alma, Michigan.
Alpena Public Library, Alpena, Michigan.
American Academy of Arts and Sciences, Boston, Massachusetts.
American Academy of Medicine, Easton, Pennsylvania.
American Association for the Advancement of Science, Washington, D. C.
American Entomological Society, Philadelphia, Pennsylvania.
American Geographical Society, New York City, New York.
American Geologist, Minneapolis, Minnesota.
American Gynecological Society, New York City, New York.
American Laryngological Association, New York City, New York.
American Midland Naturalist, Notre Dame, Indiana.

*Address all exchanges "care of the Library of the University of Michigan, Ann Arbor, Michigan, U. S. A."

American Monthly Microscopical Journal, Washington, D. C.
American Museum of Natural History, New York City. New York.
American Philosophical Society, Philadelphia, Pennsylvania.
Archives des Sciences Physiques et Naturelles, Geneva, Switzerland.
Asiatic Society of Bengal, Calcutta, India.
Astronomical Society of the Pacific, San Francisco, California.
American School of Classical Studies, Athens, Greece.
Atlanta University, Library, Atlanta, Georgia.
Bayerische Botanische Gesellschaft, Munich Germany.
Baylor University, Library, Waco, Texas.
Beloit College, Library, Beloit, Wisconsin.
Berliner Entomologischer Verein, Berlin, Germany.
Besancon University, Library, Besancon, France.
Bibliotheca Nacional, Buenos Aires, Argentine Republic.
Bibliotheca da Faculdade de Direito da Universidade, Pernambuco, Brazil.
Bibliotheque Nationale Paris, France.
Bibliotheca Nacional, Rio de Janeiro, Brazil.
Biblioteca Nazionale Centrale, Florence, Italy.
Biologiska Foerening, Stockholm, Sweden.
Birmingham School Board, Birmingham, England.
Bodleian Library, University of Oxford, Oxford, England.
Boston Medical Library, Boston, Massachusetts.
Boston Public Library, Boston, Massachusetts.
Boston Scientific Society, Boston, Massachusetts.
Boston Society of Natural History, Boston, Massachusetts.
Botanischer Verein, Freiburg-im-Breisgau, Germany.
Botanischer Verein, Koenigsberg, Prussia, Germany.
Botanischer Verein, Landshut, Germany.
Botanischer Verein Provinz Brandenburg, Berlin, Germany.
Bowdoin College, Library, Brunswick, Maine.
Bradford Scientific Association, Bradford, England.
Bristol Naturalists' Society, Bristol, England.
British Association for the Advancement of Science, London, England.
British Museum, London, England.
Brooklyn Institute of Arts and Sciences, Brooklyn, New York.
Brown University, Library, Providence, Rhode Island.
Bryn Mawr College, Library, Bryn Mawr, Pennsylvania.
The Bryologist, Brooklyn, New York.
Buffalo Society of Natural Sciences, Buffalo, New York.
Calcutta University, Library, Calcutta, India.
California Academy of Sciences, San Francisco, California.
California University, Library, Berkeley, California.
Calumet Public Library, Calumet, Michigan.
Cambridge Philosophical Society, Cambridge, England.
Cambridge University, Library, Cambridge, England.
Canadian Institute, Toronto, Canada.
Catholic University, Library, Washington, D. C.
Central State Normal School, Library, Mt. Pleasant, Michigan.
Chicago Academy of Science, Lincoln Park, Chicago, Illinois.
Chicago University, Library, Chicago, Illinois.

Cincinnati Society of Natural History, Cincinnati, Ohio.
Cincinnati University, Library, Cincinnati, Ohio.
City of London Entomological and Natural History Society, London, England.
College of Physicians, Philadelphia, Pennsylvania.
Colorado College, Library, Colorado Springs, Colorado.
Colorado School of Mines, Library, Golden, Colorado.
Colorado Scientific Society, Denver, Colorado.
Colorado University, Library, Boulder, Colorado.
Columbia University, Library, New York City, New York.
Commerz-Bibliothek, Hamburg, Germany.
Commissao Geographic e Geologica, San Paulo, Brazil.
Concilium Bibliographicum, Zurich, Switzerland.
Connecticut Academy of Arts and Sciences, Yale Station, New Haven, Connecticut.
Connecticut State Library, Hartford, Connecticut.
Cornell University, Library, Ithaca, New York.
Dalhousie College, Library, Halifax, Nova Scotia, Canada.
Davenport Academy of Natural Sciences, Davenport, Iowa.
Delaware County Institute of Science, Media, Pennsylvania.
Denison University, Scientific Laboratories, Granville, Ohio.
Denver University, Library, Denver, Colorado.
Department of Mines and Agriculture, Sidney, New South Wales.
Department of the Interior, Canadian Archives, Ottawa, Canada.
Detroit Public Library, Detroit, Michigan.
Deutsche Botanische Gesellschaft, Berlin, Germany.
Deutsche Geologische Gesellschaft, Berlin, Germany.
Deutscher u. Oesterreichischer Alpen-Verein, Munich, Germany.
Deutscher Wissenschaftlicher Verein, Santiago, Chili.
Ecole Normale Supérieure, Paris, France.
Ecole Pratique des Hautes Etudes, Sorbonne, Paris, France.
Edinburgh Field Naturalists and Microscopical Society, Edinburgh, Scotland.
Edinburgh Geological Society, Edinburgh, Scotland.
Edinburgh University, Library, Edinburgh, Scotland.
Elgin Scientific Society, Elgin, Illinois.
Elisha Mitchell Scientific Society, Chapel Hill, North Carolina.
Elliott Society of Science and Arts, Charleston, South Carolina.
Elphinstone College, Library, Bombay, India.
Entomological Society, Cavendish Square, W. London, England.
Entomological Society of Canada, Quebec, Canada.
Entomological Society of Ontario, Guelph, Canada.
Entomologischer Verein, Stettin, Germany.
Entomologiska Foerening, Stockholm, Sweden.
Essex Institute, Salem, Mass.
Field Museum of Natural History, Chicago, Illinois.
Finska Vetenskap Societet, Helsingfors, Finland.
Folia Bibliographica, Berlin, Germany.
Franklin & Marshall College, Library, Lancaster, Pennsylvania.
Geographical Society of Australia, Queensland Branch, Brisbane, Australia.

Geographical Society of California, San Francisco, California.
Geographical Society of Finland, Helsingfors, Finland.
Geographical Society of Philadelphia, Philadelphia, Pennsylvania.
Geographical Society of Quebec, Quebec, Canada.
Geographische Gesellschaft, Bremen, Germany.
Geographische Gesellschaft, Greifswald, Germany.
Geographische Gesellschaft fuer Thueringen, Jena, Germany.
Geological Society of South Africa, Johannisburg, South Africa.
Geological Survey, Department of Mines and Agriculture, Sidney, New South Wales.
Geological Survey of Missouri, Jefferson City, Missouri.
Geological Survey of Newfoundland, St. Johns, Newfoundland.
Geological Survey of New Jersey, New Brunswick, New Jersey.
Geological Survey of New Zealand, Wellington, New Zealand.
Geological Survey of Victoria, Melbourne, Victoria, Australia.
Geologische Gesellschaft fuer Ungarn, Budapest, Hungary.
Geologiska Commissionen i Finland, Helsingfors, Findland.
Georg-Augusts Universitaet, Goettingen, Germany.
Georgia University, Library, Athens, Georgia.
Glasgow Geological Society, Glasgow, Scotland.
Glasgow School Board, Glasgow, Scotland.
Glasgow University, Library, Glasgow, Scotland.
Government Botanist, Melbourne, Victoria, Australia.
Grand Rapids Public Library, Grand Rapids, Michigan.
Grossherz Bad. Albert-Ludwigs Universitaet, Bibliothek, Freiburg, Germany.
Grossherz Hessische Ludwig-Universitaet, Bibliothek, Giessen, Hessen, Germany.
Grossherz Ruprecht-Karls Universitaet, Heidelberg, Germany.
Grossherz Saechsische Gesant Universitaet, Bibliothek, Jena, Germany.
Gulf Biological Station, Baton Rouge, Louisiana.
Hackley Public Library, Muskegon, Michigan.
Hall Fowler Memorial Library, Ionia, Michigan.
Harvard Museum of Comparative Zoology, Cambridge, Massachusetts.
Harvard University, Gray Herbarium, Cambridge, Massachusetts.
Havana University, Library, Havana, Cuba.
Hillsdale College, Library, Hillsdale, Michigan.
Historical and Scientific Society, Wilmington, North Carolina.
Hrvatsko Prirodosloyno Drustvo, Agram, Croatia, Austria-Hungary.
Hull Literary and Philosophical Society, Hull, England.
Idaho University, Library, Moscow, Idaho.
Illinois Geological Survey, Urbana, Illinois.
Illinois State Laboratory of Natural History, Urbana, Illinois.
Illinois State Museum of Natural History, Springfield, Illinois.
Illinois University, Library, University Station, Urbana, Illinois.
Imperial Charkovskii Universitet, Bibliothek, Charkow, Russia.
Imperial Varsavskij Universitet, Bibliothek, Warsaw, Russia.
Imperial Institute of the United Kingdom, London, England.
Imperial Iurjevskij Universitet, Bibliothek, Dorpat, Russia.
Imperial Moskovskij Universitet, Moskow, Russia.

Imperial Moskofskoie Obshchestvo Iestestvo-Ispytatelei. Moskow, Russia.
Imperial Sankt-Petersburgskoie Mineralogicheskoie Obshchestvo, St. Petersburg, Russia.
Imperial University of Tokyo, Library, Tokyo, Japan.
Indiana Academy of Science, Indianapolis, Indiana.
Indiana Geological Survey, Indianapolis, Indiana.
Indiana University, Library, Bloomington, Indiana.
Inspectorate General of Customs, Statistical Department, Shanghai, China.
Institute de France, Paris, France.
Institute des Mines, St. Petersburg, Russia.
Institute Luxembourgeois, Section des Sciences Naturelles, Luxemburg, France.
Institute of Jamaica, Kingston, Jamaica.
Istituto Historico, Geographico y Ethynographico, Rio de Janeiro, Brazil.
Institution of Civil Engineers, Great George St., London, England.
Iowa Academy of Sciences, Des Moines, Iowa.
Iowa Geological Survey, Des Moines, Iowa.
Iowa University, Library, Iowa City, Iowa.
Iron Mountain Carnegie Library, Iron Mountain, Michigan.
Istituto Geografico Militare, Florence Italy.
Istituto Scientifico della R. Universita, Rome, Italy.
Jackson Public Library, Jackson, Michigan.
Jagellonische Universitaet, Bibliothek, Karkau, Austria-Hungary.
Jenaische Zeitschrift fuer Medicin u. Naturwissenschaften, Jena, Germany.
John Crerar Library, Chicago, Illinois.
Johns Hopkins University, Baltimore, Maryland.
K. Bayerische Botanische Gesellschaft, Regensberg, Germany.
K. Boehmische Gesellschaft der Wissenschaft, Prag, Austria-Hungary.
K. K. Deutsche Karl-Ferdinand Universitaet, Bibliothek, Prag, Austria-Hungary.
K. K. Geographische Gesellschaft, Wien, Austria-Hungary.
K. K. Geologische Reichsanstalt, Wien, Austria-Hungaria.
K. Leopoldinisch-Caroloninische Deutsche Akademie der Naturforschen, Halle-an-der-Saale, Germany.
K. K. Leopold-Franzens Universitaet, Bibliothek, Innsbruck, Tyroll, Austria.
K. Magyar Természettudományi Társulat, Tarsulat, Austria-Hungary.
K. K. Universitaet, Bibliothek, Wien, Austria-Hungary.
K. K. Zoologische-Botanische Gesellschaft, Wien, Austria-Hungary.
K. Zoologische Genootschap "Natura Artis Magistra," Amsterdam, Netherlands.
Kais Universitaet Bibliothek, Kasan, Russia.
Kaiser-Wilhelms-Universitaet, Bibliothek, Strassburg, Germany.
Kaiserliche Universitaet, Bibliothek, St. Petersburg, Russia.
Kansas Academy of Science, Topeka, Kansas.
Kansas State Historical Society and Department of Archives, Topeka, Kansas.

Kansas University, Lawrence, Kansas.
Kantonale Universitaet, Bibliothek, Bern, Switzerland.
Kentucky State College, Agricultural Experiment Station. Lexington, Ky.
Kjbenhavns Universitet, Bibliothek, Kopenhagen, Denmark.
Kongl. Albertus Universitaet, Bibliothek. Koenigsberg, Prussia, Germany.
Kongl. Alexanders Universitetet I Finland, Bibliothek, Helsingfors, Finland.
Kongl. Bayerischen Ludwig-Max.-Universitaet, Munich, Germany.
Kongl. Christian-Albrechts Universitaet, Kiel, Germany.
Kongl. Eberhard-Karls-Universitaet, Bibliothek, Tuebingen. Germany.
Kongl. Frederiks Universitet, Bibliothek, Christiana, Norway.
Kongl. Friedrich-Alexanders Universitaet, Bibliothek, Erlangen, Bayern, Germany.
Kongl. Friedrich-Wilhelms Universitaet, Bibliothek, Berlin, Germany.
Kongl. Julius-Maximilians Universitaet, Bibliothek, Wurzburg, Germany.
Kongl. Karolinska Universitetet, Bibliotheket, Lund, Sweden.
Kongl. Ungarische Universitaet, Bibliothek, Budapest, Hungary.
Kongl. Universitaet, Bibliothek, Breslau, Germany.
Kongl. Universitaet, Bibliothek, Greifswald, Germany.
Kongl. Universitaet, Muenster in Westfalen, Preussen, Germany.
Kongl. Universitetet I Upsala, Bibliothek, Upsala, Sweden.
Kongl. Zoologisches Institut, Friedrich-Wilhelms Universitaet, Berlin, Germany.
Kongliga Svenska Vetenskap Akademien, Stockholm, Sweden.
Laval University, Library, Quebec, Canada.
Leeds University, Library, Leeds, England.
Leland Stanford University, Library, Stanford University, California.
Linnean Scientific and Historical Society, Lancaster, Pennsylvania.
Linnean Society of London, Burlington House, W. London, England.
Linnean Society of New South Wales, Sydney, New South Wales.
Linnean Society of New York, New York City, New York.
Literary and Scientific Society, Ottawa, Canada.
Liverpool Geological Society, Liverpool, England.
Liverpool University, Library, Liverpool, England.
Lloyd Library, Cincinnati, Ohio.
London School Board, London, England.
McGill University, Library, Montreal, Canada.
Magyar Ornithologiai Koezpont, Budapest, Austria-Hungary.
K. Magyar Természettudományi Társulat, Budapest, Austria-Hungary.
Maine University, Library, Orono, Maine.
Manchester Geographical Society, Manchester, England.
Manchester Geological Society, Manchester, England.
Manchester University, Library, Manchester, England.
Manila University, Library, Manila, Philippine Islands.
Manitoba Historical and Scientific Society, Winnipeg, Manitoba, Canada.
Manitoba University, Library, Winnipeg, Manitoba, Canada.
Marine Biological Laboratory, Wood's Holl, Massachusetts.

Maryland Geological Survey, Baltimore, Maryland.
Massachusetts Board of Cattle Commissioners, Boston, Massachusetts.
Massachusetts Historical Society, Boston, Massachusetts.
Medicinische Naturwissenschaftliche Section des Siebenbuergischen Museum Verein, Klausenburg, Austria-Hungary.
Melbourne University, Library, Melbourne, Australia.
Michigan Agricultural College, Library, East Lansing, Michigan.
Michigan College of Mines, Library, Houghton, Michigan.
Michigan State Normal School, Library, Marquette, Michigan.
Michigan State Normal School, Library, Ypsilanti, Michigan.
Milwaukee Public Museum, Milwaukee, Wisconsin.
Minister of Public Instruction, Paris, France.
Minnesota Academy of Natural Science, Minneapolis, Minnesota.
Minnesota University, Library, Minneapolis, Minnesota.
Missouri Botanical Garden, St. Louis, Missouri.
Missouri Bureau of Geology and Mines, Rolla, Missouri.
Missouri University, Library, Columbia, Missouri.
Montana University, Library, Missoula, Montana.
Museo Civico di Storia Naturale; Trieste, Austria-Hungary.
Museo Nacional, Montevideo, Uruguay.
Museo Nacional de Buenos Aires, Buenos Aires, South America.
Museo Nacional de Historia Natural, Mexico City, Mexico.
Museu Paraense de Historia Natural, Para, Brazil.
Museu Paulista, San Paulo, Brazil.
Museum fuer Natur-u. Heimatkunde, Magdeburg, Germany.
Museum of Geology and Archaeology, Princeton, New Jersey.
Museum of Natural History, Springfield, Massachusetts.
National Academy of Sciences, Washington, D. C.
National University, Library, Athens, Greece.
Natural History and Philosophical Society, Belfast, Ireland.
Natural History Society, Exeter, New Hampshire.
Natural History Society, Montreal, Canada.
Natural History Society of Glasgow, Glasgow, Scotland.
Natural History Society of New Brunswick, St. Johns, New Brunswick.
Natural History Society of Northumberland, Newcastle-upon-Tyne, England.
Naturforschende Gesellschaft, Bamburg, Germany.
Naturforschende Gesellschaft, Basel, Switzerland.
Naturforschende Gesellschaft, Bern, Switzerland.
Naturforschende Gesellschaft, Gorlitz, Germany.
Naturforschende Gesellschaft, Leipzig, Germany.
Naturforschende Gesellschaft in Luzern, Switzerland.
Naturforschende Gesellschaft, Zuerich, Switzerland.
Naturforschender Verein, Bruenn, Austria-Hungary.
Naturhistorische Gesellschaft, Hanover, Prussia, Germany.
Naturhistorische Gesellschaft, Nurnburg, Bavaria, Germany.
Naturwissenschaftliche Gesellschaft, Chemnitz, Saxony, Germany.
Naturwissenschaftliche Gesellschaft, St. Gall, Switzerland.
Naturwissenschaftlicher Verein, Bremen, Germany.
Naturwissenschaftlicher Verein, Frankfurt-an-der-Oder, Prussia, Germany.

Naturwissenschaftlicher Verein, Hamburg. Germany.
Naturwissenschaftlicher Verein, Karlsruhe, Germany.
Naturwissenschaftlicher Verein, Lueneburg, Prussia, Germany.
Naturwissenschaftlicher Verein, Magdeburg, Saxony, Germany.
Naturwissenschaftlicher Verein, Osnarbrueck, Prussia, Germany.
Naturwissenschaftlicher Verein, Regensburg, Bavaria, Germany.
Naturwissenschaftlicher Verein fuer Saechsen u. Thueringen, Halle-an-der-Saale, Prussia, Germany.
Naturwissenschaftlicher Verein fuer Schleswig-Holstein, Kiel, Prussia, Germany.
Naturwissenschaftlicher Verein fuer Schleswig-Holstein, Kiel, Prus-Germany.
Naturwissenschaftlicher Verein fuer Steiermark, Graz, Austria.
Nebraska University, Library, Lincoln, Nebraska.
Nederlandsche Entomologische Vereeniging, Leiden, Holland.
Nevada University, Library, Reno, Nevada.
New York Academy of Medicine, New York City, New York.
New York Botanical Gardens, Bronx Park, New York City, New York.
New York Public Library, New York City, New York.
New York State Library, Albany, New York.
New York State Museum of Natural History, Albany, New York.
Norges Geologiske Undersoegelse, Christiania, Norway.
Northampton Institute, St. Johns Street Road, London, England.
North Carolina Geological Survey, Raleigh, North Carolina.
North Carolina University Library, Chapel Hill, North Carolina.
North Dakota Experiment Station, Agricultural College, Fargo, North Dakota.
North Dakota University, Library, Grand Forks, North Dakota.
Northwestern University, Library, Evanston, Illinois.
Nova Scotian Institute of Science, Halifax, Nova Scotia, Canada.
Oahu College, Honolulu, Hawaii.
Oberhessiche Gesellschaft fuer Natur-u. Heilkunde, Giessen, Hesse, Germany.
Oberlin College, Library, Oberlin, Ohio.
Observatorio do Rio de Janeiro, Rio de Janeiro, Brazil.
Oesterreichischer Reichs-Forst Verein, Wien, Austria-Hungary.
Ohio Mechanics Institute, Cincinnati, Ohio.
Ohio State Academy of Science, Page Hall, Ohio State University, Columbus, Ohio.
Ohio State Archaeological and Historical Society, Columbus, Ohio.
Ohio State University, Library, Columbus, Ohio.
Ohio Wesleyan University, Library, Delaware, Ohio.
Oklahoma University, Library, Norman, Oklahoma.
Olivet College, Library, Olivet, Michigan.
Onondaga Academy of Science, Syracuse, New York.
Ontario Minister of Education, Ottawa, Canada.
Oregon University, Library, Eugene, Oregon.
Orto Botanico, Palermo, Italy.
Oschshestvo Iestestvo-Ispytalelei pri Imper. Kazanskom Universitetie, Kazan, Russia.
Oxford University Entomological Society, Oxford, England.
Peabody Academy of Science, Salem, Massachusetts.

Peabody Institute, Library, Baltimore, Maryland.
Peabody Museum of American Archaeology and Ethnology, Cambridge, Massachusetts.
Pennsylvania Geological Survey, Philadelphia, Pennsylvania.
Pennsylvania University, Library, Philadelphia, Pennsylvania.
Perthshire Society of Natural Science, Perth, Scotland.
Petermann, Dr. A., Geographischer Mitteilungen, Gotha, Germany.
Petoskey Public Library, Petoskey, Michigan.
Phillips Academy, Department of Archaeology, Andover, Massachusetts.
Philosophical Society of Glasgow, Glasgow, Scotland.
Popular Science Monthly, Sub-station 84, New York City, New York.
Portland Society of Natural History, Portland, Maine.
Princeton Academy of Science, Princeton, Illinois.
Princeton University, Library, Princeton, New Jersey.
Provinzial-Verein fuer Wissenschaft-u. Kunst, Muenster, Prussia, Germany.
Public Gardens and Plantations, Gordon Town, Jamaica.
Public Library, Bay City, Michigan.
Public Library, Traverse City, Michigan.
Public Library and Museum, Brighton, England.
Public School, Library, Adrian, Michigan.
Purdue University, Library, Lafayette, Indiana.
Queen's College, Library, Belfast, Ireland.
Queen's College, Library, Galway, Ireland.
Queen's University, Library, Kingston, Canada.
Real Academica de Ciencias Exactes, Fisicas y Natureals, Madrid, Spain.
Real Academia de Ciencias y Artes, Barcelona, Spain.
R. Accademia delle Scienze e Belle Lettere, Naples, Italy.
R. Accademia di Scienze, Lettere ed Art, Padua, Italy.
R. Accademia di Scienze, Lettere Belle-Arti, Palermo, Italy.
Regia Superiore d' Agricoltura Biblioteca, Portici, Italy.
Regia Università degli Studi, Biblioteca, Bologna, Italy.
Regia Università degli Studi, Genoa, Italy.
Regia Università degli Naples, Biblioteca, Naples, Italy.
Regia Università degli Studi, Biblioteca, Padua, Italy.
Regia Università degli Studi, Biblioteca, Palermo, Italy.
Regia Università degli Studi, Biblioteca, Parma, Italy.
Regia Università degli Studi, Biblioteca, Pavia, Italy.
Regia Università degli Studi, Biblioteca, Pisa, Italy.
Regia Università degli Studi, Biblioteca, Rome, Italy.
Regia Università degli Studi, Biblioteca, Turin, Italy.
Regio Istituto Veneto di Scienze, Venice, Italy.
Rheinische Friedrich-Wilhelms Universitaet, Bibliothek, Bonn, Germany.
Rijksuniversiteit, Bibliothek, Groningen, Holland.
Rijks Universiteit, Bibliothek, Leiden, Holland.
Rijks Universiteit, Bibliothek, Utrecht, Holland.
Rivista Argentina, La Plata, South America.
Rivista Italiana di Scienze Naturali, Siena, Italy.

Rochester Academy of Science, Rochester, New York.
Royal Astronomical Society of Canada, Toronto, Canada.
Royal Botanic Garden, Edinburgh, Scotland.
Royal Botanic Garden, Kew, England.
Royal Botanic Garden, Sibpur, Near Calcutta, India.
Royal Botanic Society, Inner Circle, Regents Park, London, England.
Royal Dublin Society, Dublin, Ireland.
Royal Geographical Society, London, England.
Royal Geographical Society of Australasia, Adelaide, South Australia.
Royal Geological Society of Cornwall, Penzance. England.
Royal Irish Academy, Dublin, Ireland.
Royal Istituto Botanico, Palermo, Italy.
Royal London Ophthalmic Hospital, City Road, E. C. London, England.
Royal Medical and Chirurgical Society, London, England.
Royal Microscopical Society, Kings College, W. C. London, England.
Royal Society of Arts, John St., Adelphia, London. England.
Royal Society of Canada, Ottawa, Canada.
Royal Society of Edinburgh, Edinburgh, Scotland.
Royal Society of New South Wales, Sydney, New South Wales.
Royal Society of Queensland, Brisbane, Queensland, Australia.
Royal Society of South Australia, Adelaide, South Australia.
Royal Society of Tasmania, Hobarton, Tasmania, Australia.
Royal Society of Victoria, Melbourne, New South Wales.
Saellskepet pro Fauna et Flora Fennica, Helsingfors, Finland.
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Saginaw East Side Public Library, Saginaw, Michigan.
St. Andrews University, Library, St. Andrews, Scotland.
St. Francis Xavier's College, Antigonish, Nova Scotia, Canada.
St. Louis Academy of Science, St. Louis, Missouri.
San Diego Society of Natural History, San Diego, California.
School of Mines, Ballerat, Victoria, Australia.
Schweizer Entomologischen Gesellschaft, Bern. Switzerland.
Schweizerischer Forst-Verein, Zurich, Switzerland.
Scottish Natural History Society, Edinburgh, Scotland.
Seattle Public Library, Seattle, Washington.
Sheffield University, Library, Sheffield, England.
Smith College, Library, Northampton, Massachusetts.
Smithsonian Institution, Washington, D. C.
Smithsonian Institution, Bureau of International Catalogue of Scientific Literature, Washington, D. C.
Sociedad Agricola Mexicana, Mexico City, Mexico.
Sociedad Cientifica "Antonio Alzate." Mexico City, Mexico.
Sociedad Cientifica Argentina, Buenos Aires, Argentine Republic.
Sociedad de Ciencias Fisicas y Naturales, Caracas, Venezuela.
Sociedade de Geographica, Rio de Janeiro, Brazil.
Sociedad Scientifica, San Paulo, Brazil.
Società Adriatica di Scienze Naturali, Trieste, Austria-Hungary.
Società Entomological Italiana, Florence, Italy.
Società Italiana delle Scienze, Rome, Italy.
Società Italiana di Scienze Naturali, Milan, Italy.

Società Toscana di Scienze Naturali, Pisa, Italy.
Societas pro Fauna et Flora Fennieca, Helsingfors, Finland.
Société Belge d' Astronomie, Bruxelles, Belgium.
Société Belge de Géographie, Bruxelles, Belgium.
Société Belge de Geologie, Bruxelles, Belgium.
Société de Bilogique, Paris, France.
Société de Botanique du Grand-Duché de Luxembourg, Luxemburg, France.
Société de Geographie, Toulouse, France.
Société des Naturalistes de Bessarbie, Kishcinew, Russia.
Société des Sciences, Agriculture et Arts de la Basse-Alsace, Strassburg, Germany.
Société de Sciences de Nancy, Nancy, France.
Société des Sciences Historiques et Naturelles de la Corse, Bastia, France.
Société des Sciences Historiques et Naturelles de l'Yonne, Auxerre, France.
Société des Sciences Naturelles, Neuchatel, Switzerland.
Société des Sciences Naturelles, Versailles, France.
Société des Sciences Physiques et Naturelles, Zurich, Switzerland.
Société Entomologique de Belgique, Bruxelles, Belgium.
Société Entomologique de France, Paris, France.
Société Géologique de Belgique, Liege, Belgium.
Société Géologique de France, Paris, France.
Société d'Histoire Naturelle, Autun, France.
Société d'Horticulture et de Botanique, Havre, France.
Société d'Horticulture et de Botanique, Marseilles, France.
Société Linnéenne de Bordeaux, Bordeaux, France.
Société Linnéenne de Lyon, Lyon, France.
Société Linnéenne de Normandie, Caen, France.
Société Linnéenne du Nord de la France, Amiens, France.
Société Nationale des Sciences Naturelles, Cherbourg, France.
Société Royale de Botanique de Belgique, Bruxelles, Belgium.
Société Royale des Sciences, Liege, Belgium.
Sociéte Royale Linnéenne de Bruxelles, Bruxelles, Belgium.
Société Scientifique de Bruxelles, Bruxelles, Belgium.
Société Scientifique de Chevtshénko, Lemberg, Austria-Hungary.
Société Zoologique de France, Paris, France.
Society for the Development of Experimental Science, Moscow, Russia.
South African Association for the Advancement of Science, Johannesburg, South Africa.
South African Journal of Science, Cape Town, South Africa.
South Dakota Geological Survey, Vermillion, South Dakota.
State Board of Forestry, Indianapolis, Ind.
State Historical Society of South Dakota, Pierre, South Dakota.
Staten Island Association of Arts and Sciences, New Brighton, New York.
Sydney University Library, Sydney, New South Wales.
Texas Academy of Science, Austin, Texas.
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Tokio Imperial Museum, Department of Natural History, Tokio, Japan.

Toronto University, Library, Toronto, Canada.
Torrey Botanical Club, Columbia University, New York, New York.
Trenton Natural History Society, Trenton, New Jersey.
Trinity College, Library, Dublin, Ireland.
Trinity University, Library, Toronto, Canada.
Tufts College, Library, Tufts College, Massachusetts.
Ufficio Centrale Meteorologico e Geodinamico, Rome, Italy.
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Universidad de Barcelona, Bibliotheca, Barcelona, Spain.
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Université de Paris, Bibliothéque, Paris, France.
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Universitatea din Bukarest, Bibliothek, Bukarest, Roumania.
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Verein fuer Naturwissenschaften, Braunschweig, Germany.
Verein z. Verbreitung Naturwissenschaftlicher Kenntnisse, Wien, Austria-Hungary.
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Victoria and Albert Museum, Bombay, India.

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Washington Academy of Sciences, Washington, D. C.
Washington and Lee University, Library, Lexington, Kentucky.
Washington Anthropological Society, Washington, D. C.
Washington Philosophical Society, Washington, D. C.
Washington University, Library, Seattle, Washington.
Washington University, Library, St. Louis, Missouri.
Western Reserve University, Library, Cleveland, Ohio.
Western State Normal School, Library, Kalamazoo, Michigan.
Wisconsin Academy of Science, Madison, Wisconsin.
Wisconsin University, Library, Madison, Wisconsin.
Worcester Natural History Society, Worcester, Massachusetts.
Yale University, Forestry School, New Haven, Connecticut.
Yale University, Library, New Haven, Connecticut.
Yale University, Observatory, New Haven, Connecticut.
Yorkshire Geological and Polytechnical Society, Halifax, England.
Zentral-Bibliothek, Munich, Germany.
Zoological Society, Fairmount Park, Philadelphia, Pennsylvania.
Zoologischer Anzeiger, Leipzig, Germany.
Zurich University, Library, Zurich, Switzerland.

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